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THE IMPACT OF POST-FARMGATE VALUE-ADDED ACTIVITIES ON WESTERN CANADIAN AGRICULTURE

by

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ABSTRACT

In recent years in Canada, direct support provided by governments to the agricultural sector has been decreasing due to international obligations under the General Agreement on Tariff and Trade/World Trade Organization (GATT/WTO) and the North American Free Trade Agreement (NAFTA). Consequently, governments and the agriculture industry are exploring ways of generating and sustaining farmers' revenue from the marketplace. There is a renewed interest in the concept of "post-harvest value adding" by the federal and provincial governments and the agriculture industry, and substantial investment has been made in value-added initiatives in the post-farm-gate sector.

The purpose of this thesis is to assess the impacts of post-farm-gate value added activities on western Canadian agriculture. Value adding activities in the form of research and development projects in the post-farm-gate sector are assumed to result in increased demand for primary commodities produced in western Canada. Thus, the thesis aims at assessing the effects of value adding on the production of primary commodities, prices and the welfare of farmers. Primary commodities that are considered here include wheat, barley, canola, slaughter cattle and slaughter hogs.

The procedure adopted to achieve the objectives of the thesis is first, to establish the type of relationships among the commodities considered in the study using a Leontief function. Second, the nature of the market for these primary commodities is assessed using a Translog function. Finally, simulation experiments are conducted to provide insights into the effects of the assumed increased demand for commodities resulting from

post-harvest value adding activities. The effects assessed are changes in prices, quantities and producer welfare in the form of profits.

The results indicate significant economic interrelationships among wheat, barley, canola, slaughter cattle and slaughter hogs at the farm sector. Wheat production and barley production appear as complements but canola production appears to be a substitute for wheat production. Hog production is positively related to the prices of wheat, barley and canola. Cattle production is positively related to the price of barley. The results indicate jointness in the production of hogs and barley. On the issue of the existence of market power held by processors, there is no evidence of non-competitive behaviour in any of the commodity markets examined.

Results from the simulation exercises indicate that an increase in the price of one commodity results in an increase in the production of that commodity and a fairly constant or decline in the production of others. An implicit assumption underlying the simulation model is that land is fixed, so that there is competition for the land resource in production. Farmers' welfare is increased significantly with an increase in the price of grains/oilseed. Experiments conducted by increasing the quantity of commodities demanded on the domestic market revealed a very small effect on commodity prices. As a result, the increase in farmers' profits is also minimal. Changes in quantity variables did not trigger changes in price variables, suggesting that in Canada, commodity prices are exogenously determined, predominantly by situations in the international market.

University of Alberta

Faulty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "The Impact of Post-Farm-Gate Value-Added Activities on Western Canadian Agriculture" in partial fulfillment of the requirements of the degree of Doctor of Philosophy in Agricultural Economic.

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Thanks to the academic and administrative staff of Rural Economy department for making the department a pleasant place to study. Each one of them contributed in one way or the other to my successful study at the department. Thanks also to my fellow graduate students for sharing ideas with me.

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1. INTRODUCTION

1.1 Introduction

In recent years in Canada, domestic government policies are being undertaken to reduce budget deficits. Direct support provided by governments to the agricultural sector is being reduced due to international obligations under the General Agreement on Tariffs and Trade/World Trade Organization (GATT/WTO) and the North American Free Trade Agreement (NAFTA). For example, in 1995, the Western Grain Transportation Subsidy (WGTS) was eliminated, altering the economics of agricultural production and food processing in western Canada. Faced now with higher grain transportation rates, farmers in the Canadian Prairies (the provinces of Manitoba, Saskatchewan and Alberta) have to explore new ways for sustaining the farming business. The problem facing farmers is further aggravated with the cyclical nature of agricultural markets and volatile commodity prices. If agricultural production and productivity remain at constant levels and long run declining trends in commodity prices continue, farmers' revenues per unit of production are likely to decline over time in the absence of any government support. These developments confronting farmers are creating the necessity for governments and the agriculture industry to explore ways of generating and sustaining producers' revenue from market sales and revenues. They also pose immediate challenges for adaptation and adjustment through diversification, expansion and value-added processing activities beyond the farm gate[1].

On the demand side, consumer studies indicate that many consumers are tending to consume more differentiated, higher quality products. Health concerns seem to be high among various factors guiding many consumers' choice of food (Beggs et al. 1993; Capps and Schmitz 1991; Quagrainie 1995). In addition, the Canadian population is undergoing a change in ethnic and age mix. These developments in the demand for food in Canada provide opportunities to develop value-added foods and non-traditional ethnic foods for both the domestic markets and for export.

1.2 Government Initiatives on Value-Adding

The agricultural sector in the Canadian Prairies is characterized by the production of grains, oil-seeds and livestock. A greater part of the farm products is shipped and marketed as raw, bulky and unprocessed farm commodities. The value of processed food and beverages is low relative to the value of unprocessed farm commodities (Table 1.1). The ratio of the two values is less than one and it appears to be stable (Figure 1.1). These values reflect the relatively lower level of value added to primary agricultural products in the Prairies compared to Ontario. Consequently, the potential for increased value-added processing has attracted much attention by both the federal and the Prairie governments. The annual rate of growth in processed food and beverages in the prairies is less than 5%. From 1988 to 1997, the average annual growth rate of processed food and beverages is calculated as 4.9% for Alberta, 4.4% for Saskatchewan, and 2.9% for Manitoba.

In 1996, the Alberta government provided $35 million in seed money towards the establishment of a new, not-for-profit Alberta institution, the Alberta Value Added Corporation (AVAC). This corporation was created to foster research and development into the commercialization of value-added products with a focus on the agriculture and

[1] In this study, the concept of value adding refers to any activity that increases the value of raw agricultural commodities through processing. It includes improvement in quality and the production of alternative

food sector. Also in 1996, the Saskatchewan government instituted an Agri-Value Program (AVP). The purpose of the program is to encourage the development of agriculture-related, value-added industries in that province. In 1997, Manitoba Agriculture and Agriculture and Agri-Food Canada introduced the Agri-Food Research and Development Initiative (ARDI). This initiative is meant to encourage, promote, and conduct innovative research and development projects that contribute to economic development, sustained prosperity, and successful adaptation in the changing agricultural trading environments. The objective of these value-added initiatives is to induce post-harvest value-added growth in most sectors of the prairie agricultural economy. It is hoped that this may have a broad and potentially huge economic impact at the farm level as a result of increased demand for primary commodities produced in the Prairies.

1.3 Problem Statement

Development of post-harvest value-added activities should be viewed as part of a continuous, complex economic development process within the food system. The effectiveness of value-added initiatives on the farm sector demands an understanding of the whole economic process. First, long-term growth in value-adding activities depends primarily on growth in effective demand for value-added products and on production of agricultural raw materials. Demand for food is a function of income, prices, taste and demographic factors. Empirical evidence suggests that food is price inelastic, although elasticity measures for various categories of food may differ. On the other hand, the supply of raw agricultural commodities depends primarily on expected prices and exogenous factors such as technology and weather.

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products that meet consumer approval.

Second, the food production process is a multi-stage production system. Figure 1.2 is a simplified chart illustrating product flow and the marketing system in Canada. There are intra- and inter-relationships between the grains and livestock sectors. For example, interrelationships exist between beef and pork, and between barley and slaughter hog production. Thus, any value adding in cereals may have a significant impact on the livestock industry and vice versa.

Third, any investments can change the structure of the production technology in the processing sector. Figure 1.3 depicts two possible effects of value-added investments assuming the prices of the inputs used are held constant. The curves are isoquants of a farm commodity **X1** and a marketing input **X2**, the inputs used by the processor. In one scenario, an increase in processors' output from $\mathbf{Q}^0$ to $\mathbf{Q}^1$ causes an increase in the use of both inputs, i.e., giving a parallel shift in the isoquants. In this case more output is produced using more of the farm commodity and the marketing input. The same proportion of the inputs is used in the production process (from point **a** to **b**). Alternatively, as output increases from $\mathbf{Q}^0$ to $\mathbf{Q}^1$, the amount of **X1** used increases but the amount of **X2** used declines. In this scenario, there is a change in the shape and position of the isoquant. More of the farm commodity input is used relative to the marketing input (from point **c** to **d**).

Fourth, the value-adding policy initiatives involve publicly funded investments and policy makers should have information about payoffs in order to assess alternative uses for these public funds. There is a public interest issue also about the productivity of tax dollars. Besides farmers, other identifiable groups in the marketing system are processors, marketing input suppliers and consumers. Each of these agents may be affected by policies on value adding. The size and distribution of any value-added based benefits/costs can be expected to depend on market structure. Consequently, there is a need to evaluate the size and distribution of benefits/costs of this policy among the various groups. Clearly, there are several factors at play in the food production process that need to be understood if the impact of post-harvest value adding is to be assessed appropriately.

1.4 Objectives of the Study

The primary objective of the thesis is to simulate the likely impact of value adding on commodity prices, quantities, and welfare of farmers. However, given the complex process within the food system, this study also examines the linkages among consumers, processors and grain and livestock farmers in the prairie region using econometric modelling methods. Three crops and two livestock commodities are considered in this study, namely wheat, feed barley, canola, slaughter cattle and slaughter hogs. These are major farm commodities produced in western Canada. Specifically, the objectives of the study are:

1. to examine the interrelationships in commodity production at the farm level in the Prairies,
2. to evaluate food supply and farm commodity demand relationships in the processing sector in Canada,
3. to evaluate the existence of any oligopsony power in the domestic market for primary farm commodities because in Canada, there are relatively few primary food processing establishments compared to the number of farm businesses suggesting

there is the potential that these processing establishments will exert some market power in the domestic market for farm commodities.

4. to investigate short run and long run demand for food in Canada, and
5. to simulate the likely impact of value adding on commodity prices, quantities, and welfare of farmers.

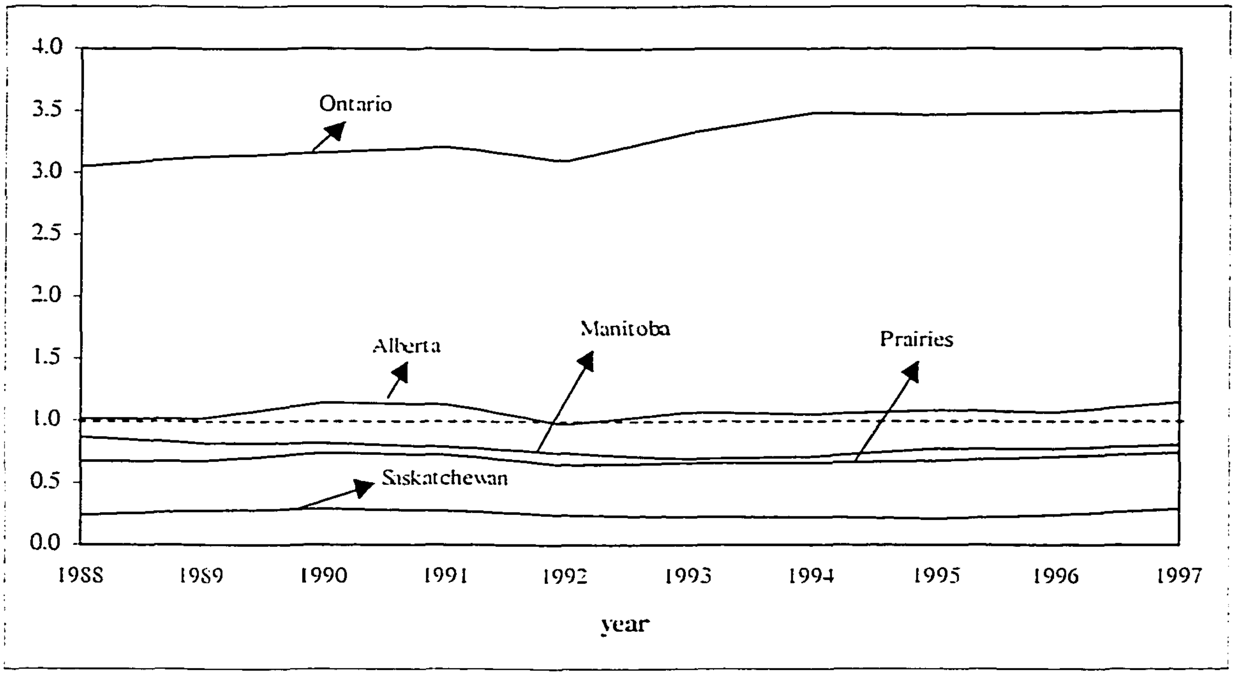
To accomplish these objectives, models of the production of wheat, barley, canola, slaughter cattle and slaughter hogs are estimated using a Generalized Leontief function. Using Translog specifications, the supply functions for wheat flour, canola oil and meat products and the demand functions for farm commodities are specified so that the extent of any oligopsony power in the domestic market for primary farm commodities can be determined. To investigate the short run and long run demand for food in Canada, a dynamic linear version of the almost ideal demand system (LAIDS) is used. The functional forms used allow the evaluation of cross commodity effects. These supply and demand relationships are then incorporated into a synthetic simulation model to investigate the likely impact of increased value-added processing on commodity prices, quantities, and welfare of prairie farmers.

1.5 Relevance of the Study

The procedure applied here is expected to provide results that will give an insight into the relationships among the five commodities considered (wheat, feed barley, canola, slaughter cattle and slaughter hogs). An insight into the relationships at the farm level is very important as farm managers are determining their best strategies for future profit and farm growth. Results from the simulation analyses will assist governments in evaluating their policies for the agricultural sector and provide a framework for future policy decisions, particularly in the allocation of public resources. In addition, the study will provide insights into the short run and long run patterns of food consumption in Canada. This is also important for policy planning purposes.

The thesis is presented as follows: In Chapter 2 there is an examination of the production of wheat, feed barley, canola, slaughter cattle and slaughter hogs in the prairie region. The production of crops and livestock is examined simultaneously. In Chapter 3, the economic behaviour of the Canadian food-processing sector is examined to assess whether or not oligopsony power applies in this sector. The rationale for this assessment is that the distribution of economic benefits from investment in value-added activities depends on market structure. In Canada, there are relatively few primary food processing establishments compared to the larger number of farm businesses and production. Thus, in the absence of more competition for farm commodities from the export market, concern has been expressed that these processing establishments will exert some market power in the domestic market for farm commodities. In Chapter 4 the demand for food in Canada is investigated. The final chapter incorporates the estimated supply and demand relationships in Chapters 2, 3 and 4 into a static synthetic simulation model. The model is then used to simulate the likely impact of value adding on prices, quantities, resource allocation and net benefits to western Canadian farmers, processors and consumers.

Figure 1.1: Ratio of the Value of Shipments of Processed Food to the Value of Output of Unprocessed Farm Production



Source: Calculated from Table 1.1.

Figure 1.2: A Simplified Diagram of Product Flow and the Marketing System for Food in Canada

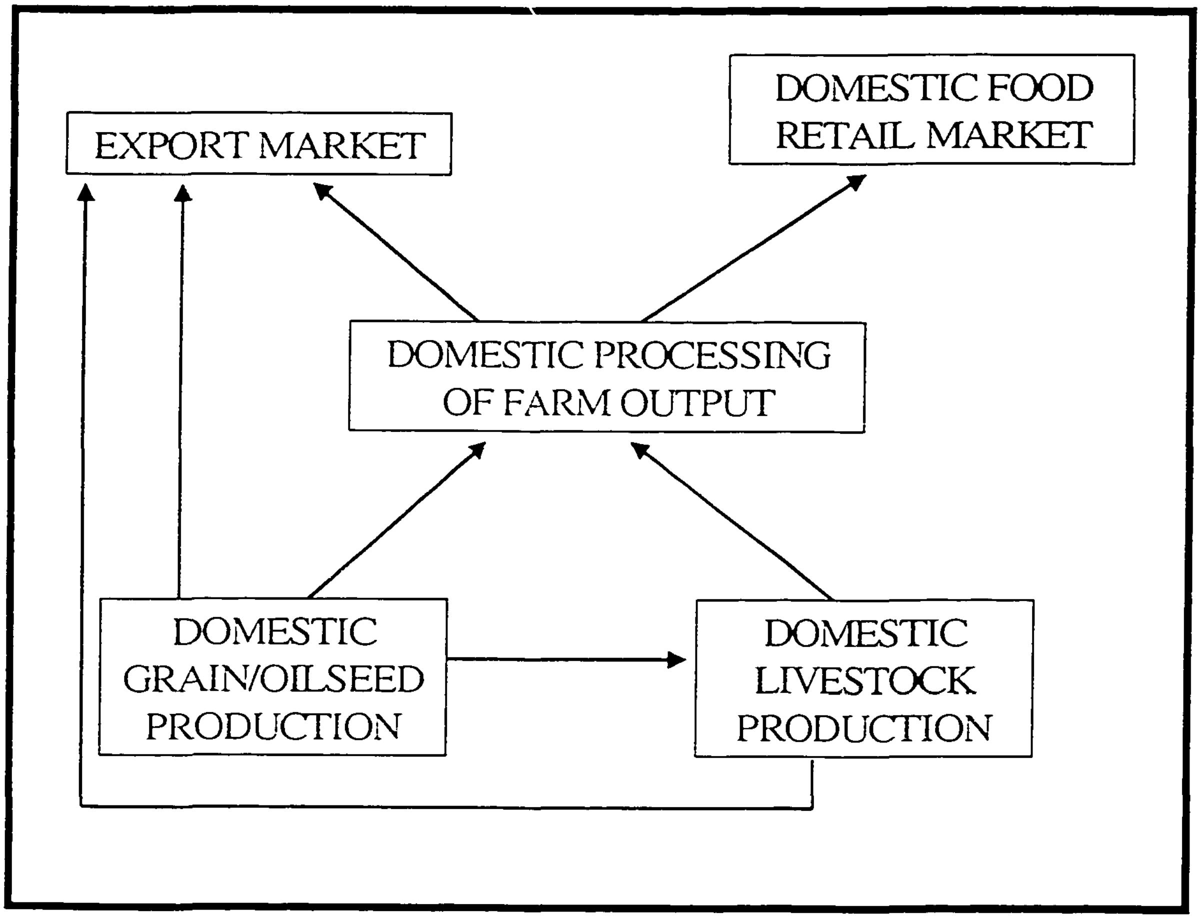
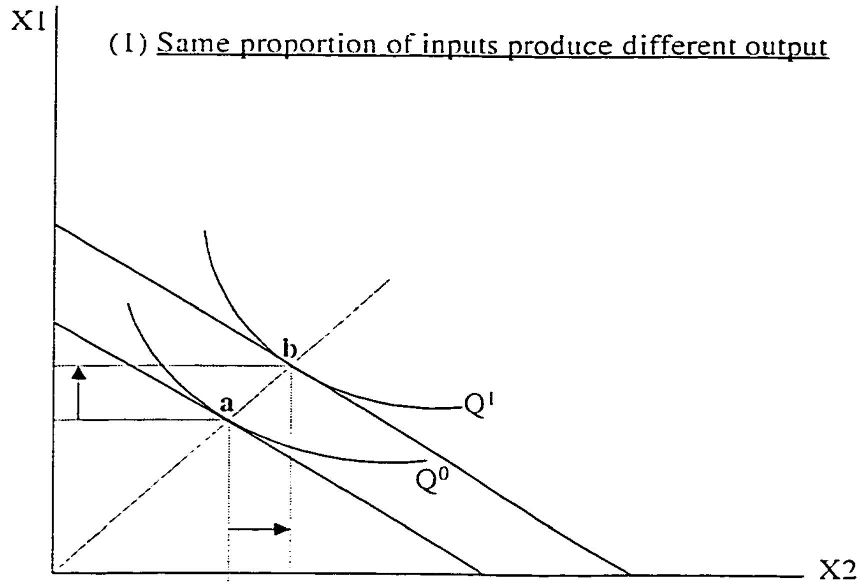


Figure 1.3: Alternative Possible Impacts of Value Added Investments on Processors' Input Use



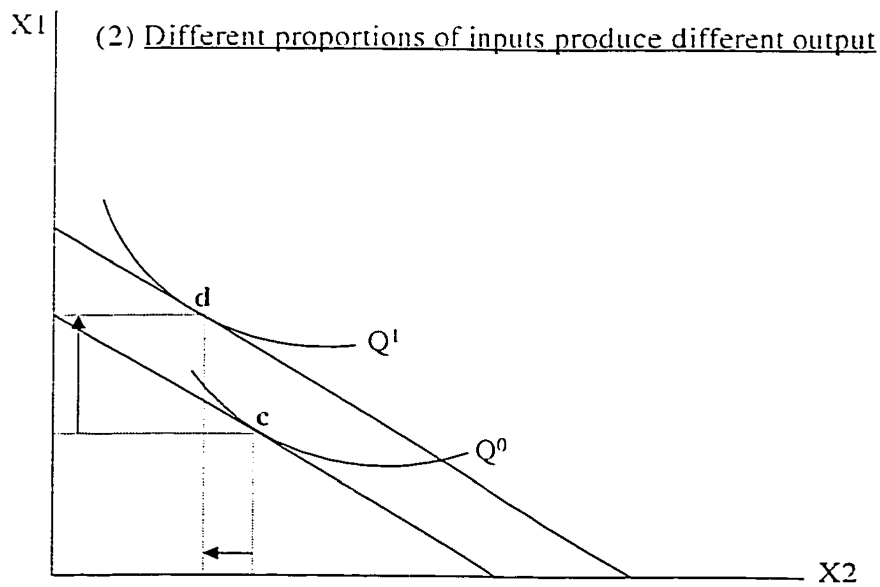


Table 1.1: **Nominal Values of Processed Food and Unprocessed Farm Commodities of some Selected Provinces ($billion)**[1]

Year	Value of Processed Food & Beverage ($billion)					Value of Unprocessed Farm Commodities ($billion)				
	Alberta	Sask.	Manitoba	Prairie	Ontario	Alberta	Sask.	Manitoba	Prairie	Ontario
1988	4.51	1.10	1.81	7.42	17.53	4.46	4.46	2.09	11.01	5.76
1989	4.64	1.20	1.73	7.57	18.07	4.59	4.49	2.10	11.18	5.77
1990	4.89	1.16	1.64	7.69	17.87	4.28	4.02	1.98	10.28	5.66
1991	4.78	1.11	1.57	7.46	17.80	4.23	4.12	2.00	10.35	5.55
1992	4.74	1.06	1.59	7.39	18.76	4.92	4.38	2.16	11.46	6.06
1993	5.29	1.01	1.66	7.96	19.70	5.00	4.55	2.38	11.93	5.92
1994	5.76	1.10	1.74	8.60	21.15	5.52	5.05	2.44	13.01	6.07
1995	6.33	1.16	1.94	9.43	21.87	5.89	5.37	2.51	13.77	6.31
1996	6.84	1.35	2.15	10.34	22.93	6.44	5.48	2.75	14.67	6.57
1997	7.25	1.70	2.42	11.37	23.72	6.34	5.90	3.03	15.27	6.77

[1] Source: Statistics Canada (CANSIM). In CANSIM, the terminology "value of shipment of food and beverage" applies as the measure of the value of processed food and beverage and the data on "farm receipts" is applied as the measure of the value of output of unprocessed farm commodities.

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2. SUPPLY RESPONSE OF WESTERN CANADIAN AGRICULTURE

2.1 Introduction

Long-term growth in post-harvest value-adding activities depends not only on growth in effective retail demand, but also on the supply of agricultural raw materials. The supply of agricultural products depends on expected price and other exogenous factors including technology, weather and government policy. There are production interrelationships in the farm sector. Some major livestock feed inputs like barley are obtained from crop production so that production decisions in the crop sector are directly associated with production decisions in the livestock sector. Moreover, major government policy decisions may change the economic environment affecting the crop sector and this may have an impact on the livestock sector. Even within the crops sector, changes in the economic factors affecting one crop may have some impact on other crops. It is, therefore, important to examine these interrelationships at the farm level to enable a better prediction of farmers' behaviour resulting from increased value-added activities in the processing sector and any increased demand for farm output.

Changes in the economic environment affecting the agricultural sector can be expected to affect farm commodity prices. Often farmers' responses to changes in the agricultural economic environment are assessed in terms of the response of commodity supply to changes in prices. However, in the short run, some factors of production may be irreversibly committed to particular uses. An important example of this type of input is farmland. It is important, then, to examine farmers' ability to make long run structural adjustments in response to any broad-based changes that may confront the farm sector from increased value-added activities in the processing sector.

This component of the thesis is organized as follows. The section that follows gives a brief review of studies on commodity supply in western Canada. Based on the review, the objectives of the study are outlined. This section is followed by an outline of a theoretical framework on which the models to be estimated are based. In this section, the formulation for incorporating farmland allocation decisions and the formulation for examining the total effect of a price change are developed. The formulations that are developed involve alternative ways of specifying a system of supply response models: these have not been applied in previous studies of western Canadian agriculture. Supply functions are specified as being conditional on farmland allocations using a Generalized Leontief profit function. Following this are sections dealing with the empirical specification of the models, data description, estimation methods and presentation of estimation results. Some conclusions are then drawn from the estimation results.

2.2 Literature Review of Western Canadian Agriculture

Various studies of western Canadian agriculture have examined different modelling issues that include functional forms, the effects of government policy and technological changes, and risks. For example, Bewley et al. (1987), Coyle (1993b). Horbulyk (1990), Krakar and Paddock (1985), and Meilke and Weersink (1991) examined different functional forms for supply response models. Given that there are risks associated with the business of farming, Meilke and Weersink (1990, 1991), Schoney (1990, 1995), and Weisenel et al. (1991) introduced producer risk into supply response models for the prairie region. Other researchers have examined the effects of price expectations on farmers' supply functions (Clark and Klein 1992; Clark et al.

1992). Carew et al. (1992) also investigated how technological changes brought about by agricultural research have influenced Canadian agriculture.

Another important issue that has confronted prairie farmers during the past two decades includes changes in government agricultural policy. Agricultural policies that have affected prairie agriculture include the Western Grains Stabilisation Program (WGSP), the Western Grain Transportation Subsidy (WGTS), as well as crop insurance and safety net programs. In 1990, the WGSP was abandoned in favour of an expanded crop insurance program and in 1995, WGTS was eliminated. Studies that have examined the impact of government programs include Cameron and Spriggs (1991), Cluff et al. (1990), Coyle and Brink (1990), Fulton (1987), Meilke (1976), Meilke and Weersink (1990), and Miranda et al. (1994). Results from these studies have suggested that there is little or no impact of the WGSP on acreage allocations.

This portion of the thesis builds on previous economic research on western Canadian agriculture in a number of ways. First, the studies cited above have analysed crops and livestock sectors separately, implicitly assuming weak separability between these two sectors in western Canada[2]. This assumption is somewhat restrictive and may be inappropriate if results are to be used for policy analyses since, as noted earlier, interrelationships exist between the livestock sector and the crops sector in western Canadian agriculture. This study examines supply response in the livestock and crops sectors simultaneously to enable a better prediction of farmers' behaviour.

[2] The concept of weak separability involves aggregation to construct broad groups of commodities (e.g., crops and livestock) as well as separable decision making for each of the group subproblems. This assumption permits the specification and estimation of a subgroup of commodities in isolation from other commodities.

Second, Coyle (1993b) examined western Canadian farmers' response incorporating farmland allocation for a four-crop model of wheat, barley, canola and "other" crops using data over the period 1961-1984. However, farmland is viewed as a quasi-fixed agricultural input that is allocatable not only to the production of wheat, barley, canola, oats, and "other" crops, but also to the production of tame hay (seeded hay as opposed to native grass) and for summer fallow. Hay is an important feed input for livestock and tame hay is increasingly becoming a commercial crop in western Canada. In 1960, 1.83 million hectares of land was seeded to tame hay in western Canada (Statistic Canada – CANSIM). In 1998, 4.45 million hectares of farmland was seeded to tame hay, an increase of about 143 percent. Despite decreases in this practice, summer-fallow is still a primary rotation practice in arid cropping areas of western Canada (Clark and Klein 1992). This study incorporates farmland allocation to the production of wheat, barley, canola, and tame hay, as well as considering land allocation to summer-fallow.

Finally, the present study examines farmers' ability to make long run adjustments by distinguishing between:

(a) a change in supply induced by a price change holding allocatable farmland constant (viewed as partial effects of a price change) and

(b) a change in supply associated with reallocation of farmland, in response to the price change (referred to as complete effects of the price change).

In summary, the models to be used in this component of the study include three crops (wheat, barley and canola) and two livestock activities (cattle and hogs). The models incorporate farmland allocation in the production of wheat, barley, canola and tame hay as well as land allocation to summer-fallow. Results from this model will assist in providing a means of assessment and prediction of the effects of shifts in economic conditions on crop and livestock production and on farmland allocation in western Canada.

2.3 Theoretical Framework

This section outlines the economic theory of production and its application to the western Canadian farm sector. The "total" effect of price changes on farm production, based on interrelations between alternate farmland uses, is examined.

2.3.1 Basic Model Formulation

The approach of duality to production economics is applied in this study. The essence of the dual approach is that technology constrains optimizing behaviour of individuals. Thus, it is possible to use a representation of optimizing behaviour (e.g., cost minimization, profit maximization) to study technology (Chambers 1988). In addition, the dual approach avoids explicit specification of production functions and permits the specification of a system of output supply functions from the dual profit or cost function. This procedure is appropriate when dealing with multiple commodities and/or products. It permits the incorporation of contemporaneous covariances of disturbances across equations in the estimation procedure and the specification of symmetry restrictions on coefficients across equations that are implied by theory. Consequently, a duality approach is appropriate to examine interrelationships between the crop and livestock sectors to enable an effective assessment of the effect of a price change on the production of other commodities.

Consider the farming business in western Canada as being a competitive industry with the objective of a farmer operating a multi-output farm enterprise being maximization of short run profit. A farmer's decision problem is then described as:

$$\Pi(w,r,d,z) = \max_{q,x} \{wq - rx \ : \ q \in Q(x,d,z)\} \qquad (2.01)$$

where $q = (q_1,\ldots, q_m)$ is a vector of outputs for m enterprises; $w = (w_1,\ldots, w_m)$ is a vector of output prices; $x = (x_1,\ldots, x_v)$ is a vector of variable inputs; $r = (r_1,\ldots, r_v)$ is a vector of variable input prices; $d = (d_1 ,\ldots d_n)$ is a vector of exogenous variables (e.g., weather and interest rates); z is a fixed input that can be allocated among m enterprises (e.g., total farmland) with $z \geq \sum_{i=1}^{m} z^i$, where z^i is farmland allocated to the i^{th} enterprise; and Q is the output set (i.e., the set of feasible outputs given x, d and z).

Equation (2.01) is an expression of the maximum level of variable profit (i.e., revenue minus variable cost) given the exogenous factors and the fixed input. Given standard assumptions for the underlying technology[3], the profit function is non-negative, reflecting the property of monotonicity, as well as being convex and continuous in (w, r), non-decreasing in w, non-increasing in r, and positively linearly homogenous in (w, r). By *Hotelling's lemma*, optimal output supply (q_i) and input demand functions (x_j) are obtained respectively as:

$$q_i(w,r,d,z^1,\ldots,z^m) = \frac{\partial \Pi(w,r,d,z^1,\ldots,z^m)}{\partial w_i} \qquad i = 1,2,\ldots,m \qquad (2.02)$$

and

$$x_j(w,r,d,z^1,\ldots,z^m) = -\frac{\partial \Pi(w,r,d,z^1,\ldots,z^m)}{\partial r_j} \qquad j = 1,2,\ldots,n \qquad (2.03)$$

[3] The assumption is that the input requirement set is convex, closed and non-empty for all q>0 (i.e., all input combinations capable of producing output level q).

All variables are as defined earlier. The output supply and input demand expressions are functions of all output prices, all variable input prices, exogenous factors and the fixed input.

An alternative expression of the farmer's decision problem equation (2.01) is:

$$\Pi(w,r,d,z) \;=\; \max_{q}\{wq - c(r,q) \;:\; (q,d,z^1,\ldots,z^m)\in\tau\} \tag{2.04}$$

where $c(r,q)$ is the cost function of the farm enterprise and τ is the technology set. Again, assuming standard properties for τ, the cost function is non-decreasing in r and q, concave and continuous in r and linearly homogenous in r. If the underlying production technology is assumed to be homothetic, the cost function can be written as[4]:

$$c(r,q) \;=\; c(r)g(q) \tag{2.05}$$

where $g(q)$ is a function that is non-decreasing in q; and $c(r)$ is now the cost function associated with a unit output, that is,

$$c(r) \;=\; \min\{wx:(x,1)\in\tau\}. \tag{2.06}$$

With this technology, the profit function, $\Pi(w,c(r),d,z)$ is linearly homogenous in w and $c(r)$, and $c(r)$ is linearly homogenous in r, that is,

$$\Pi(w,d,z,r^*) \;=\; c(r)\Pi^*(w,d,z/c(r)) \tag{2.07}$$

where $r^*=c(r)$ represents a single aggregate input price index; and Π^* is a function homogenous of degree zero in the output price and the aggregate input price (Chambers 1988 p. 149). Thus, the profit function can be expressed as; (1) a linearly homogenous function of output prices w, exogenous variables d, fixed allocatable input z, and a single

[4] The homothetic assumption permits researchers to construct aggregate price and quantity indices to study production decisions by analysing only a subgroup of all outputs and input (e.g., Coyle 1993a; Lawrence 1989; Paris et al. 1990; Pope and Hallam 1988; Roberts 1989; Yuhn 1991).

aggregate input price r^*; and (b) a product of r^* and Π^* (Chambers 1988 p. 149; Coyle 1993a; Pope and Hallam 1988; Yuhn 1991). The aggregate input price may be defined as the cost-minimizing way of producing q. The short run profit-maximzing output supply functions are a system of equations represented by:

$$q_i(w,r^*,d,z^1,\ldots,z^m) = \frac{\partial \Pi(w,r^*,d,z^1,\ldots,z^m)}{\partial w_i} \qquad i=1,2,\ldots,m \qquad (2.08)$$

where $q_i(w,r^*,d,z^1,\ldots,z^m)$ is the profit-maximizing output supply of the i^{th} farm commodity. The above model expresses output supply as a function of all output prices, a single aggregate input price, the exogenous factors and the fixed input. An expression for the effect of a change in output price is:

$$\frac{\partial^2 \Pi(w,r^*,d,z)}{\partial w_i \partial w_j} = \frac{\partial q_i(w,r^*,d,z)}{\partial w_j} \qquad (2.09)$$

The above formulation expresses a change in output supply induced by a price change (partial effect), ignoring the effect of the change in allocatable fixed input, z (indirect effect). It assumes that allocation of a fixed input such as farmland is independent of output prices which implies that the shadow price or marginal value of land is independent of output prices.

2.3.2 *Modelling Fixed Allocatable Input*

Chambers and Just (1989) suggest that when there is a fixed allocatable input such as farmland, an equivalent approach for obtaining the multi-output profit function is to choose the fixed allocatable farmland to maximize the profit function, that is:

$$\Pi(w,r^*,d,z) = \max_{z^1,\ldots,z^m} \left\{ \Pi(w,r^*,d,z^1,\ldots,z^m) : \sum_{i=1}^{m} z^i = z \right\} \qquad (2.10)$$

Equation (2.10) is the profit function associated with an optimal allocation of the fixed allocatable input. Given the standard assumptions concerning technology, this function is also convex and continuous in (w, r), non-decreasing in w, non-increasing in r, and linearly homogenous in (w, r). If an interior solution ($z^i > 0$) to (2.10) exists for all i, the envelope theorem and *Hotelling's lemma* give:

$$\begin{aligned} \frac{\partial \Pi (w_i, r^*, d, z)}{\partial w_i} &= q_i(w, r^*, d, z^1, \ldots, z^m) \\ &= q_i(w, r^*, d, \bar{z}^1, \ldots, \bar{z}^m) \\ &= \frac{\partial \Pi (w, r^*, d, \bar{z}^1, \ldots, \bar{z}^m)}{\partial w_i} \end{aligned} \qquad (2.11)$$

where $\bar{z}^i$ is the optimal fixed input allocation[5]. The formulation above offers a decomposition of output response to price changes that illustrates the importance of the effects of output price changes on farmland values. Based on (2.10), the effect of output price change may be specified as:

$$\frac{\partial q_i(w, r^*, d, z)}{\partial w_j} = \frac{\partial q_i(w, r^*, d, \bar{z})}{\partial w_j} + \sum_{i=1}^{m} \sum_{k=1}^{s} \frac{\partial q_i(w, r^*, d, \bar{z})}{\partial z_k^i} \left\{ \frac{\partial \bar{z}_k^i}{\partial w_j} \right\} \qquad (2.12)$$

where $i=1,\ldots,m$ refers to supply and $k=1,\ldots,s$ refers to reallocated fixed input such as farmland. Horbulyk (1990) and Chambers and Just (1989) refer to the expression on the right side of (2.12) as the "total" effect of a price change. The expression may also be termed the "complete" effect of a price change. The first part expresses the change in supply induced by the price change (partial effect) holding the allocatable fixed input constant. The second part expresses the change in supply associated with reallocation of fixed input in response to the price change (indirect effect). Chambers and Just (1989)

[5] The envelope theorem applied here makes use of the fact that the first order conditions of equations (2.04) and (2.10) always hold with equality at the optimal values of q_i.

refer to the partial effect as the compensated effect (compensated for the induced fixed input change). The term in brackets is obtained from the first-order conditions of (2.10) with respect to z^i since the profit function contains the optimal fixed input allocations.

Diewert (1974), and Khatri and Thirtle (1996) suggest that land is a short run constraint on production. Therefore, in the long run, the effect of land is relaxed and the shadow value of land is obtained by differentiating the profit function with respect to land. Hence the shadow value of land is interpreted as the marginal change in profits for an increment in land, or as the imputed rental value of an additional unit of land (Khatri and Thirtle 1996). In equilibrium, the shadow prices of optimal allocated farmland are equalized, that is:

$$\frac{\partial \Pi(w, r^*, d, \bar{z})}{\partial z^k} = \frac{\partial \Pi(w, r^*, d, \bar{z})}{\partial z^1} \tag{2.13}$$
$$= r_z(w, r^*, d, z) \qquad k = 1, \ldots, s$$

where $r_z(.)$ is the equilibrium shadow price of farmland allocation. From the above expression, the change in supply associated with reallocation of fixed input in response to the price change can be obtained.

2.3.3 *Input Non-jointness*

The concept of input non-jointness is important in supply response models because it enhances econometric simplicity by implying that either the cost function $c(r,q)$ or the profit function $\Pi(w,r,d,z)$ can be modelled by their single-enterprise counterparts with no loss of generality (Chambers 1988, p. 293). This implies that both the profit and cost functions of a multi-output enterprise are the sum of the m enterprises, that is:

$$\begin{aligned}\Pi(w,r,d,z) &= \max_{q}\{wq-\sum_{i=1}^{m}c^{i}(r,q_i)\} \\ &= \sum_{i=1}^{m}\max\{w_i q_i - c^{i}(r,q_i)\} \\ &= \sum_{i=1}^{m}\Pi^{i}(w,r,d,z)\end{aligned} \tag{2.14}$$

Input non-jointness derives from aggregation across farm enterprises. From (2.14), when z is truly fixed, Ball (1988) and Moschini (1988) show that input non-jointness implies:

$$\frac{\partial^2 \Pi(w,r^*,d,z)}{\partial w_i \partial w_j} = \frac{\partial q_i(w,r^*,d,z)}{\partial w_j} = 0 \tag{2.15}$$

Equation (2.15) can be used to test non-jointness in production. However, given (2.12), the use of (2.15) to test non-jointness is inappropriate. Chambers and Just (1989) show that where z is an allocatable fixed input, the appropriate test for non-jointness in production is:

$$\begin{aligned} &\frac{\partial q_i(w,r^*,d,z)}{\partial w_j}=0 && i,j=1,\dots,m, \quad i\neq j \\ &\frac{\partial q_i(w,r^*,d,z)}{\partial z_k^i}=0 && i,j=1,\dots,m; \quad k=1,\dots,s \\ &\frac{\partial r_z(w,r^*,d,z)}{\partial z_k^i}=0 && k=1,\dots,s \end{aligned} \tag{2.16}$$

The hypothesis of non-jointness among various farm enterprises in western Canada can be tested in a straightforward manner using (2.16).

2.4 Empirical Specification

The first step in formulating the empirical model is to choose an appropriate functional form to parameterize the profit function of (2.04). Using the envelope theorem as applied in (2.11), supply functions can be obtained. These supply functions are estimated together with the first order conditions for an optimal fixed input allocation from equation (2.13). The inclusion of (2.13) in the estimation process suggests a long run framework since the allocation of farmland is not fixed (Diewert 1974; Khatri and Thirtle 1996)[6]. Such a formulation permits the examination of the long run production structure of prairie agriculture and the extent of interrelationships among crop and livestock enterprises. More importantly, the total effect of a price change including reallocation of farmland among farm enterprises can be examined.

As noted earlier, this study employs duality formulations as described above to examine the production of wheat, barley, canola, slaughter cattle and hogs in western Canada, i.e., in the provinces of Manitoba, Saskatchewan, Alberta and British Columbia. The fixed allocatable input considered here is farmland, which is allocated to wheat, barley, canola, summer fallow and tame hay. The functional form used in the study is the Generalized Leontief profit function (Diewert 1974) which is a second-order Taylor series expansion, linear in parameters and imposes few maintained hypotheses. The Generalized Leontief function has quantity as the dependent variable which allows easy implementation and interpretation of results, especially when model specifications are to be used for policy analyses (Martin and Alston 1994). The function is convenient for examination of comparative statics and imposing and testing theoretical restrictions. The Generalized Leontief function also allows explicit solutions of shadow values for the allocatable farmland. Other functional forms that have the expenditure share as the dependent variable (e.g., the translog function) do not allow this. An explicit solution of

[6] When farmland is truly fixed and not allocatable between crops or land uses (i.e., in the short run), only the system of supply functions of (2.08) is estimated.

the shadow value for farmland is particularly important in this study because one of the study objectives is to assess long run adjustments in farmland use.

In spite of these advantages, the Generalized Leontief functional form has some limitations. It imposes assumptions with respect to quasi-homotheticity of the production technology (Chambers 1988, p. 173-177: Lopez 1985)[7]. A quasi-homothetic technology has straight-line expansion paths such as a homothetic technology except that these expansion paths do not emanate from the origin. The assumption of quasi-homotheticity is necessary in permitting the construction of aggregate price and quantity indices to study production decisions by analysing only a subgroup of outputs or input. In this study, the primary focus is on farm output. Therefore, the demand for individual variable farm inputs is not considered in the modelling procedure. The quasi-homotheticity assumption allows the use of a single aggregate input price index as a *numeraire* in the model. The *numeraire* price index is used to normalize the prices in the model, thereby imposing homogeneity.

Following Shumway and Lim (1992), and Villezca-Becerra and Shumway (1992) the Generalized Leontief profit function of the four-crop and two-livestock farm enterprise with optimal farmland allocation is represented as follows:

$$\begin{aligned}\Pi \;=\; & \alpha_0 + 2\sum_{i=1}^{5}\alpha_i w_i^{0.5} + 2\sum_{k=1}^{5}\beta_k z_k^{0.5} + 2\sum_{t=1}^{3}\gamma_t d_t^{0.5} + \sum_{i=1}^{5}\sum_{j=1}^{5}\alpha_{ij} w_i^{0.5} w_j^{0.5} \\ & + \sum_{k=1}^{5}\sum_{l=1}^{5}\beta_{kl} z_k^{0.5} z_l^{0.5} + \sum_{t=1}^{3}\sum_{u=1}^{3}\gamma_{tu} d_t^{0.5} d_u^{0.5} + \sum_{i=1}^{5}\sum_{k=1}^{5}\delta_{ik} w_i z_k \qquad (2.17) \\ & + \sum_{i=1}^{5}\sum_{t=1}^{3}\lambda_{it} w_i d_t + \sum_{k=1}^{5}\sum_{u=1}^{3}\phi_{ku} z_k d_t\end{aligned}$$

where Π = profit for the farm enterprise divided by an input price index;

w_i = price of the output divided by an input price index, and indexed $i,j = 1,\ldots,5$ to represent the production of wheat, barley, canola, cattle and hogs respectively;

z_k = allocated farmland, and indexed $k,l = 1,\ldots,5$ to represent hectares of wheat, barley, canola, tame hay and summer fallow respectively; and

d_t = quasi-fixed/exogenous factors, and indexed $t,u = 1,\ldots,3$ to represent cattle inventory, hog inventory and interest rate respectively. The rationale for including livestock inventories is that managers of livestock farms make production decisions involving livestock numbers, quality standards and weight produced per head. Therefore, production is the result of previous resource commitments and biological factors (Horbulyk 1990; Marsh 1999).

The first order conditions of equation (2.17) with respect to output prices give the short run output supply functions:

$$\frac{\partial \Pi}{w_i} = q_i(w,z,d) = \frac{\alpha_i}{w_i^{0.5}} + \alpha_{ii} + \sum_{j=2}^{5} \alpha_{ij} \frac{w_j^{0.5}}{w_i^{0.5}} + \sum_{k=1}^{5} \delta_{ik} z_k + \sum_{t=1}^{3} \lambda_{ut} d_t \quad i \neq j \qquad (2.18)$$

Based on (2.13), the first order condition of (2.17) with respect to z_k gives the long run equilibrium market price (shadow price) of allocated farmland which is expressed as:

$$\frac{\partial \Pi}{z_1} = r_z(w,z,d) = \frac{\beta_k}{(z_1)^{0.5}} + \beta_{kk} + \sum_{l=2}^{5} \beta_{kl} \frac{(z_l)^{0.5}}{(z_1)^{0.5}} + \sum_{u=1}^{3} \phi_{ku} d_u + \sum_{j=1}^{5} \delta_{kj} w_j \quad k \neq l \qquad (2.19)$$

Parameters from the models are obtained by estimating (2.18) and (2.19) together as a system of seemingly unrelated regressions. As alluded to earlier, inclusion of (2.19) in the estimation process suggests a long run framework since farmland is not fixed. The system

[7] This is a general limitation of flexible functional forms. Chambers (1988, p. 173-179) provides a thorough

is made up of six equations that includes supply equations for wheat, barley, canola, slaughter cattle, and hogs and one equation for optimal land allocation[8].

Economic theory of the firm requires that the properties of the profit function be satisfied. These are monotonicity, symmetry, and homogeneity and convexity in output prices. Monotonicity implies producers do not accept negative profits, which requires that the dependent variables fitted with the estimated coefficients be positive ($\hat{q}_i \geq 0$). The convexity property requires that all estimated own-price effects be positive ($\hat{\alpha}_i \geq 0$). The properties of homogeneity and symmetry are imposed during estimation but the properties of monotonicity and convexity are tested after the estimation. Two major issues are examined in the study. The first is the evaluation of the partial effect of price changes on producers' response in terms of the production of wheat, barley, canola, cattle and hogs and assuming farmland allocation is unchanged. The second is the evaluation of the total effect of price changes on production of wheat, barley, canola, cattle and hogs that includes the effect of price changes and reallocation of farmland.

2.5 Data Requirements

Data required for estimating the models outlined above include production quantities and prices of wheat, barley, canola, slaughter cattle and slaughter hogs; area allocated to wheat, barley, canola, tame hay and summer-fallow; cattle and hog inventories: and the Canadian commercial interest rate, a proxy for the price of capital. A complete description of variables and data sources is provided in Table 2.1. The data

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discussion concerning the limitations of flexible functional forms.

[8] From equation (2.13), the shadow prices of optimal allocated farmland are equalized thus, only one equation is required which is specified for wheat because it is the dominant crop.

series used in the study were scaled by their respective means because the data series vary significantly from each other in terms of values. For example, annual data series on commodity production and acreage allocations are expressed in millions, prices are expressed in hundreds and tens, and interest rate is expressed in decimals. Scaling of the data series by the respective means ensures uniformity in the data set (Coyle 1993b).

Statistics Canada provided most of the required data. This includes production estimates of wheat, barley, and canola in western Canada. For livestock, Statistics Canada provided estimates of national production, not regional production. However, Agriculture Canada provided regional marketings of slaughter cattle and hogs. Production of slaughter cattle and hogs in western Canada is obtained by converting total marketings in heads into tonnes using an estimated national conversion rate. The rationale behind this conversion is that carcass weight for slaughter cattle and hogs in Canada has changed over the years, probably from improvements in animal genetics and feeding technology (see Figures 2.1 and 2.2). In the U.S., changes in animal genetics and feed nutrition have resulted in heavier carcasses and higher carcass yields (Brester et al. 1997). This suggests that beef and pork supplies are now more dependent upon livestock productivity. Consequently, the average national carcass weight for Canada is calculated and applied to total livestock marketings in western Canada from 1960 to 1997.

The value of farmland in Saskatchewan is used as a proxy for the equilibrium price (shadow price) of allocated farmland. There is high correlation between the value of farmland in Saskatchewan and that in Manitoba and Alberta. The correlation coefficient between farmland values in Saskatchewan and Manitoba is 0.95; between farmland values in Saskatchewan and Alberta is 0.97; and between farmland values in Manitoba and Alberta the correlation coefficient is 0.99. A larger percentage of crop production occurs in Saskatchewan than in any other western province.

Grain prices are specified to be the prices received by western Canadian farmers for selected grain of specified grades (Table 2.1). Canola price series were obtained from Statistics Canada and Canadian Grains Council with different time lengths. A procedure using linear regression is applied to obtain the series that is used in the study (see Appendix 2a). For livestock, prices in Alberta are used because a larger percentage of livestock production in western Canada occurs in that province. Cattle prices are assumed to be represented by slaughter cattle price in Lethbridge and southern Alberta where there ais relatively large concentration of cattle production. For hogs, the average price for Alberta is used. Definitions and sources of other variables used in the study are provided in Table 2.1.

2.6 Estimation Procedure

A common problem with estimating a system of equations for commodities is multicollinearity among price variables. Researchers have often addressed this problem by adopting extremely restrictive functional forms and arbitrarily omitting some price variables (e.g., Burt and Worthington 1988; Shumway et al. 1987). This type of *ad hoc* approach may ignore many cross-price effects. A better approach to minimize the problem of multicollinearity among prices may be to adopt restrictions on coefficients implied by behavioural theory, such as symmetry conditions. Alternatively, specifying supply response models in terms of revenues per acre rather than prices may reduce the problem (e.g., Bewley et al. 1987; Coyle 1993b). The reason for adopting this type of specification is that revenues per acre for different crops are often less correlated than are crop output prices. Alternatively, one of the price variables could be used to scale the other price variables to minimize multicollinearity (e.g., Coyle 1993b). This study uses commodity prices and imposes restrictions on coefficients implied by the symmetry conditions. Moreover, the Generalized Leontief function that is used for the model specifications incorporates price ratios (scaled prices) which will minimize the problem of multicollinearity.

The four-crop and two-livestock supply model (equations 2.18 and 2.19) for western Canada is specified using annual data for the region from 1960 to 1997. Dependent variables in equation (2.18) are annual production figures, in tonnes, for the six commodities from 1960 to 1997[9]. In equation (2.19), the dependent variable is the shadow price of farmland. Explanatory variables in the system are the price per tonne of wheat, barley, canola, slaughter cattle, and slaughter hogs; acreage in hectares seeded to wheat, barley, canola, and tame hay; area allocated to summer-fallow; cattle and hog inventories; and interest rate from 1960 to 1997. The interest rate is used as a proxy for the price of capital.

The empirical formulation outlined in section 2.4 is based on farmers' expected prices of commodities. However, Pope (1982) contends that under risk neutrality, all dual properties of profit maximization that apply in the certainty case for *ex ante* choices also apply to expected profit maximization in the uncertainty case, so that expected prices can be substituted by presumed known prices. Thus, for wheat and barley, the average of

[9] While estimation of supply relationships has been conducted using acreage planted to crops and livestock numbers as dependent variables, other studies have emphasized production (e.g., Arzac and Wilkinson 1979; Chambers and Just 1989; Clark et al. 1992; Coyle 1993a; Hayenga and Hacklander 1970; Kulshreshtha and Reimer 1975; Shumway et al. 1987).

prices in the previous two years is used as a proxy for expected price. For canola, one-year lagged price is used for expected price. Livestock prices are current prices.

The process of normalization maintains global homogeneity. That is, the profit function and supply equations are homogenous of degree zero in all prices as each price is divided by an aggregate input price index. A proportionate change in all prices thus has no impact on optimal production quantities. The second partial derivatives of the profit function are invariant to the order of differentiation so that the commodity supply equations are symmetrical in normalized prices (i.e., $\alpha_{ij}=\alpha_{ji}$ for $i\neq j$). Symmetry conditions are imposed during estimation. The disturbances in (2.18) and (2.19) are linearly dependent because, from the empirical formulation, acreage allocation is not a predetermined variable since it varies with price changes. Moreover, cattle and hog inventories are considered as endogenous variables. All data used are from secondary sources and may have some errors in the measurement. Thus, all the model specifications are estimated as a system of equations using the iterative three-stage least square (3SLS) regression techniques of the "SHAZAM" software program (Judge et al. 1988 p. 650; Kennedy 1992 p.161-162; White 1978). The Canada-U.S. exchange rate, U.S. corn and U.S. soybean prices are used as instrumental variables in addition to the explanatory variables in the system of equations.

Non-jointness in production is tested using equation (2.16) to verify whether production of commodities is independent of one another. Four tests are performed. First, non-jointness in production of all enterprises is tested in each supply equation. Second, non-jointness in production of the 3-crop enterprises is tested in each of the crop equations. Third, non-jointness in production of the 2-livestock enterprises is tested in each of the livestock equations. Finally, non-jointness in production between barley and hogs is tested in both the barley supply and hogs supply equations.

2.7 Results and Discussion

2.7.1 Model Diagnostics

A common econometric problem associated with the use of time series data in applied econometric work is spurious regression resulting from trending variables (Dickey and Fuller 1979). For example, if two variables both trend upward, a regression of one on the other is likely to find a "significant" relationship between them, even if the only thing they have in common is the upward trend. In this case, the results of such studies may be of limited use in conducting impact analysis. Therefore, a unit root test (Augmented Dickey-Fuller test) was conducted for all the variables used in the specifications. Results from the tests are reported in Table 2.2, which that the variables have different structures. For example, the null hypothesis of unit root is rejected for the variables hay production, land price, hog/wheat ratio, hog/barley ratio, hog/canola ratio, canola/hog ratio and wheat acreage. These variables are said to be stationary in levels but the others are not.

The presence of non-stationary variables raises the possibility of cointegrating or long run relationships in the models estimated. In this study, the possibility of estimating actual long run relationships is not verified because the common approach to estimation of a system of equations involving cointegrated variables developed by Johansen (1988), uses differenced variables in a vector autoregression (VAR). Some differenced variables have negative signs and cannot be used in the Generalized Leontief model. Moreover, there are limitations to the use of VAR techniques regarding the number of variables to include in the cointegration test. With more than one cointegrating relation, there is ambiguity in the interpretation of the estimated cointegrating vectors (Johansen 1988). Each of the estimated models in this study involves 13 variables. An alternative to differencing the data is the use of price ratios to estimate a system of equations involving cointegrated variables. The Generalized Leontief function used for the model specifications incorporates price ratios.

The estimated coefficients, values of R-squared, variance of estimates and Durbin-Watson statistics are presented in Table 2.3. To gain insight into the statistical properties of the estimated models, scrutiny of the measure of R-squared values indicates a reasonable fit. This R-squared is not the goodness-of-fit measure which is calculated as one minus the ratio of the residual variance over the variance of the left-hand side (unexplained portion of the total variance) [10]. Rather, it is a measure between observed and predicted dependent variables (White 1993 p.12). R-squared values range from a high of 0.99 for the canola production equation to a low of 0.86 for the wheat production equation. The Durbin-Watson statistics, which measure the presence of first-order autocorrelation in the models, are also reasonable, suggesting autocorrelation is not a problem in these models.

Homogeneity and symmetry were imposed during estimation, but monotonicity and convexity in prices were not. Monotonicity requires that all dependent variables fitted with the estimated coefficients be positive. All estimated models at every data point satisfy monotonicity. This implies that producers do not accept negative profits and that

[10] In 3SLS estimation the goodness-of-fit measure of R-squared is not well defined (Berndt 1991, p. 468; Judge et al. 1988 p. 650).

there is no negative supply. Positive own-price elasticities are necessary conditions for satisfying the property of convexity. This condition is also satisfied in all the models and is consistent with the fundamental property of supply that supply increases with an increase in price.

2.7.2 *Estimation Results*

In interpreting the results it should be noted that data were scaled by the respective means, so that, some coefficient estimates may be interpreted as partial elasticity measures, evaluated at the respective means. This applies specifically to acreage allocations, cattle numbers, hog numbers and the interest rate. The formulation for calculating partial elasticity of supply with respect to changes in own-price is presented in Appendix 2b. For ease of interpretation, estimated coefficients are reported in Table 2.3 and estimates of the partial elasticities are reported in Table 2.4. Table 2.5 compares some partial elasticity estimates from this study to estimates from selected studies of supply response for western Canada. Total elasticity estimates based on the expression in equation (2.12) are reported in Table 2.6.

As expected, the supply of each of the commodities has a positive relationship with own price. From Table 2.3, the parameter estimate for wheat price in the wheat equation is 0.037, the parameter estimate for barley price in the barley equation is 0.183, and the parameter estimate for canola price in the canola equation is 0.212. For livestock, the parameter estimate for slaughter cattle price in the slaughter cattle equation is 0.320, and the parameter estimate for slaughter hog price in the hog equation is 0.124. The positive signs confirm the convexity property of the profit function from which the supply functions were derived. They also reaffirm the fundamental property of supply that the commodity supply curves are upward sloping.

2.7.3 *Partial Price Responsiveness*

Table 2.4 reports the estimated partial elasticity measures for the economic variables. All own-price elasticity measures have a positive sign as expected. Estimated own-price elasticities are 0.449, 0.498, 0.064, 0.123 and 0.830 for wheat, barley, canola, cattle and hog production respectively, and estimates for barley and hogs are asymptotically significant at a 5% level. This implies that, in the long run, farmers respond positively to changes in barley and hog prices by altering production accordingly and that the supply functions for these commodities are positively sloped. Hog production is the most price-elastic among the five commodities. This appears to be a reasonable finding, since annual data are used and the hog cycle (from birth to market) is about 12 to 18 months. Consequently, inventory of animals can be reduced readily with high market prices within this time frame. Cattle production has a longer cycle, about 3 to 3½ years and inventory reduction may not be readily accomplished as with hogs. Thus, the estimated elasticity of cattle supply of 0.123 appears reasonable.

Cross-price effects among the commodities have signs that are reasonable and reflect cropping patterns in western Canada but most estimates are not statistically significant asymptotically. Hog production is positively related to wheat, barley and canola prices. Estimated elasticities of hog production with respect to changes in wheat, barley and canola prices are respectively, 0.294, 0.24 and 0.209 (Table 2.4). Estimates of hog production with respect to wheat and barley prices are statistically significant. Since hog production is expressed as pigs marketed in western Canada, the positive relationship suggest that as grain/oilseed prices increase, there is an increase in the number of pigs marketed. Wheat is a minor component of livestock feed but barley and canola meal are major feed components, so that increasing grain/oilseed prices can imply increasing feed cost. Profit maximizing hog producers will probably reduce inventory by marketing more animals if there are increasing costs of production. This argument may not be applicable to cattle because of the relatively long cycle.

Wheat production and barley production appear as substitutes in production with canola production. The estimated parameters on canola price in the wheat and barley production equations are -0.054 and –0.151 respectively. Wheat (barley) production has a positive relationship with barley (wheat) price, indicating complementarity in production. Though the estimated cross-price elasticities for these crops are not statistically significant, the signs on the estimates reflect the cropping pattern in western Canada. In the 1970s, 1980s and 1990s, wheat production averaged 13.9, 19.7 and 22.3 million tonnes respectively. Barley production in the same periods averaged 9.8, 11.1 and 11.8 million tonnes while canola production averaged 1.8, 2.5 and 4.1 million tonnes. From these figures, wheat, barley and canola production increased, on the average, by about 60%, 20% and 128% respectively from the seventies to the nineties, reflecting the increasing popularity of canola production among farmers during this period. Comparison of the increase in production since the 1970s suggests increasing substitution of wheat and barley production with canola production. Scrutiny of the elasticity estimates of commodity production with respect to acreage allocations confirms this trend of cropping. Supply elasticities with respect to acreage allocations are discussed in a later section.

Comparison of the partial supply elasticity measures with those from previous studies is difficult because of different variable definitions, time periods and model specifications. However, Table 2.5 provides both the partial price elasticity measures estimated in this study and those obtained in selected studies of supply response of western Canadian farmers. In terms of absolute values, own-price elasticity estimates from previous studies are quite different from those estimated in this study. For wheat, barley and canola, estimates from Meilke and Weersink (1991) are relatively larger than estimates from this study. For livestock, estimates from this study and that from Coleman and Meilke (1988) suggest cattle supply is price-inelastic while hog supply is relatively price-elastic. In Table 2.5, cross-price elasticities for wheat and barley indicate a complete contrast in results in terms of signs. Both Coyle (1993b) and Meilke and Weersink (1991) find wheat and barley to be substitutes in production. In this study, wheat and barley are found to be complementary in production. The difference might be due to differences in time periods and model specifications. The dependent variable in the specifications in Coyle (1993b) and Meilke and Weersink (1991) are seeded area rather than production, as in this study. The data period also varies (Table 2.5). Nevertheless, all three studies find wheat/barley and canola to be substitutes in production.

2.7.4 *Partial Responsiveness to Non-Price Variables*

From Table 2.4, the acreage allocation to wheat, barley and canola are positively related to the production of wheat, barley and canola; 0.589, 1.17 and 0.842 respectively.

The estimates for barley and canola are statistically significant asymptotically. These findings are expected since crop production depends on acreage planted.

Regarding the effects of cross-acreage allocations, signs on the elasticity estimates are mixed. For example, the estimate on acreage seeded to barley is positive (0.271) in the wheat production equation but the estimate on land allocated to wheat in the barley production equation is negative (-0.247). However, there is consistency in the sign on estimates on cereal grain (wheat and barley) production with respect to acreage allocation to canola. The supply elasticity of wheat with respect to canola acreage allocation is –0.231, and the supply elasticity of barley with respect to acreage allocation to canola is –0.171. Both estimates are statistically significant, which reaffirms the substitutability between grains and canola production indicated earlier. Farmland allocated to summer-fallow is negatively related to the production of wheat, barley and canola. The estimates are negative and statistically significant asymptotically with values of –0.869, -0.684, and –0.8 respectively. This result probably reflects competition among crop enterprises and the farming practice of summer-fallow for farmland. Acreage allocated to tame hay is positively related to the production of wheat, barley and canola.

For livestock, cattle production is positively related to cattle inventory with an estimate of 0.658 and hog production is positively related to pig inventory with an estimate of 0.148 (Table 2.4). The estimate of cattle inventory is statistically significant asymptotically. Cattle production also appears positively related to acreage allocated to tame hay acreage but negatively related to acreage allocated to wheat, barley, canola, and summer-fallow. This result is expected since hay production is a major component of cattle production enterprises in western Canada. The estimate of cattle production with respect to tame hay acreage is 0.347. Hog production appears positively related to area allocated to barley and tame hay with estimates of 0.35 and 0.843 respectively (Table 2.4). The production of hogs is, however, negatively related to acreage allocated to wheat, canola, and summer-fallow. The effect of interest rate (the price of capital) on commodity production is quite low on all commodities with estimates ranging from –0.009 to 0.011. All estimates are statistically insignificant asymptotically.

2.7.5 Total Price Responsiveness

The total elasticity measure expresses the change in supply induced by a price change as well as the change in supply associated with reallocation of farmland in response to the price change (see Appendix 2b). Total elasticity measures of price changes on production are reported in Table 2.6. Out of the 25 estimated elasticity measures, 9 are deemed asymptotically significant. All own-price elasticity measures have signs that are consistent with the results reported in Table 2.4. These own-price elasticity measures of production, shown on the diagonal of Table 2.6, have positive signs. A positive total own-price elasticity implies that production increases in response to increases in price, even when land allocations are allowed to change. The production of wheat and hog production is price-elastic in terms of total effects. Hog production is the most price elastic in production among the five commodities with a total own-price elasticity measure of 1.204. Canola production is the least elastic in production with a total own-price elasticity measure of 0.614. Canola production is also found to be the least elastic among the partial own-price elasticity measures in Table 2.4. In terms of the size of own-price estimates, total own-price elasticity measures are larger in size than are the partial own-price elasticity measures reported in Table 2.4. For example, the partial and total own-price elasticity measures for wheat are 0.449 and 1.058 respectively; barley, 0.498 and 0.741 respectively; canola, 0.064 and 0.411 respectively; cattle, 0.123 and 0.614 respectively and hogs, 0.830 and 1.204 respectively.

Regarding total cross-price elasticity measures, there are no prior expectations in terms of signs (see formulations in Appendix 2b). As a theoretical and empirical issue, elasticity measures can be positive or negative. In Table 2.6, most commodities appear as complements in production. There are positive total cross-price elasticity measures, except for wheat production with respect to canola price.

2.7.6 Tests of Non-jointness in Production

Various tests of non-jointness in production are performed using equation (2.16). Non-jointness in production implies that both the cost and profit functions of the multi-commodity enterprises are the sum of the single-commodity cost and profit functions (Chambers 1988, p. 293). Hence, the test of non-jointness may be regarded as a test of independence in production (null hypothesis). First, non-jointness is tested in the production of all enterprises. Then, non-jointness in production of only the three-crop enterprises is tested in each of the crop equations. The third test of non-jointness involves production of only the two-livestock enterprises and the final test involves non-jointness in production between barley and hogs. Formulations for the parametric tests of non-jointness are presented in Appendix 2c. Results of these tests are reported in Table 2.7. The second, third and fourth tests of non-jointness are more intuitive and are commented on below.

Consistent with Shumway et al. (1987), joint production of grains and oilseed is evident from the second test. The hypothesis of non-jointness of production of wheat, barley and canola is rejected at the 5% level in each of the crop equations (Table 2.7, column 3). This implies that the production of individual grains/oilseed in western Canada is not independent of one another. Jointness in production of the three crops wheat, barley and canola may be due to technical interdependence and/or to the presence of allocatable farmland or rotational limitations. All three crops are commonly planted on the same farm in a given year in western Canada. Thus, they often compete for the same land, labour and managerial resources. Differences in the relative importance of technical interdependence and allocatable inputs may result in the nature of the economic interdependence between any pair of production activities being either complementary or competitive in production (Shumway et al. 1987).

The null hypothesis of non-jointness in the production of cattle and hogs is not rejected at the 5% level in any of the livestock equations (Table 2.7, column 4). Non-jointness in production of cattle and hogs may be due to technical independence in the production process. In western Canada, cattle production and hog production are independent as each production process requires different husbandry and managerial skills. The null hypothesis of non-jointness in the production of barley and hogs is rejected at the 5% level suggesting that barley production is not independent of hog production. That seems to suggest that the barley and hog industries are closely tied together.

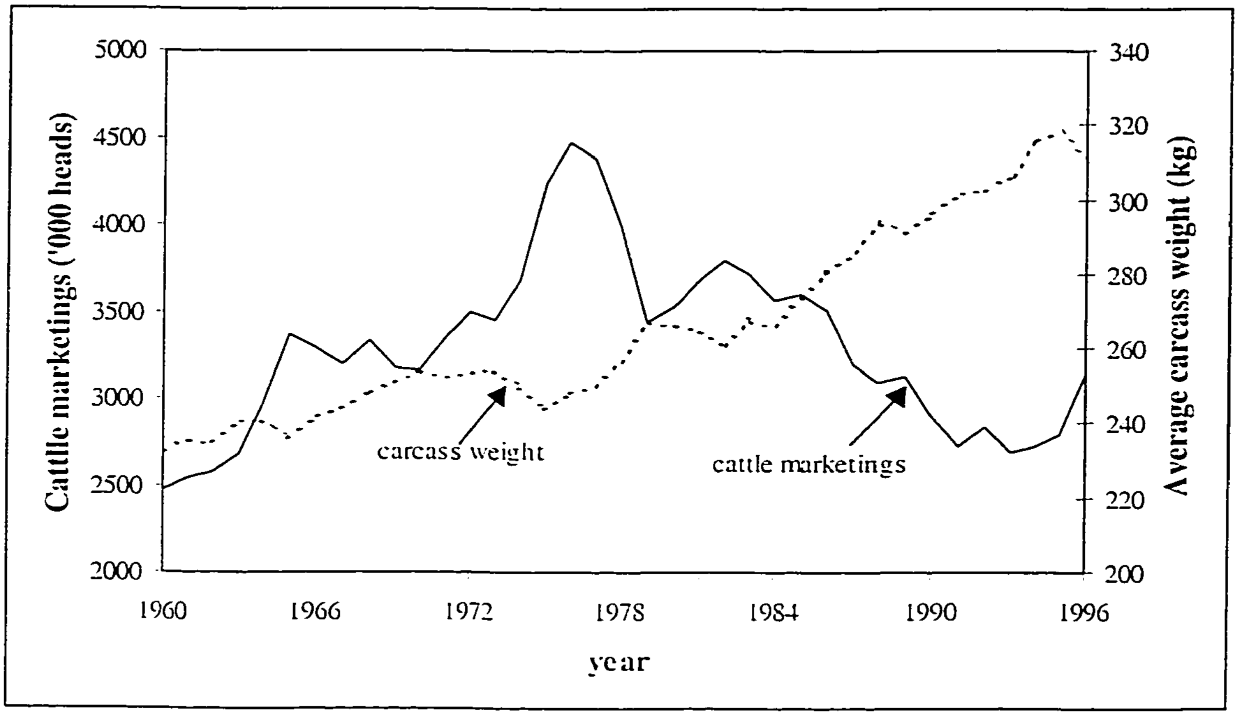
2.8 Summary and Conclusions

The objective of this section of the study was to specify and estimate the supply response of western Canadian agriculture. The study examined a model of three crop (wheat, barley and canola) and two livestock activities (cattle and hogs) which incorporated farmland allocation in the production of wheat, barley, canola and tame hay, as well as land allocation to summer-fallow. Previous regional studies have ignored farmland allocation to tame hay and summer-fallow in their analyses and have not examined the crops and livestock sectors simultaneously. Supply functions derived from the Generalized Leontief profit function were specified and estimated simultaneously for the crops and livestock sectors using annual data from 1960 to 1997. The study assessed the extent of substitution/complementarity in production among the five commodities and the effects of price changes on production resulting directly from changes in price as well as indirectly from farmland reallocation. The statistical and economic implications of the models were assessed.

The results indicate significant economic interrelationships in the western Canadian agricultural sector. The partial and total effects of price changes on production are examined and these results show that the quantity supplied of each of the commodities examined is positively related to its own price. Hog production is the most price-elastic among the five commodities examined suggesting that inventory of animals can be reduced readily for slaughter with high market prices. Canola production is the least price-elastic. Wheat production and barley production appear as complements but canola production appears to be a substitute to wheat production. Hog production is positively related to the prices of wheat, barley and canola. Cattle production is positively related to the price of barley. A chi-square test of non-jointness in production indicates jointness in the production of grains and oilseeds, non-jointness in the production of cattle and hogs and jointness in the production of hogs and barley. These findings of complementarity and substitution provide insights into the potential effect of increased value added activities in the processing sector on the farm sector. We also gain insights into the potential effects that changes in the economic conditions of one commodity may have on other commodities.

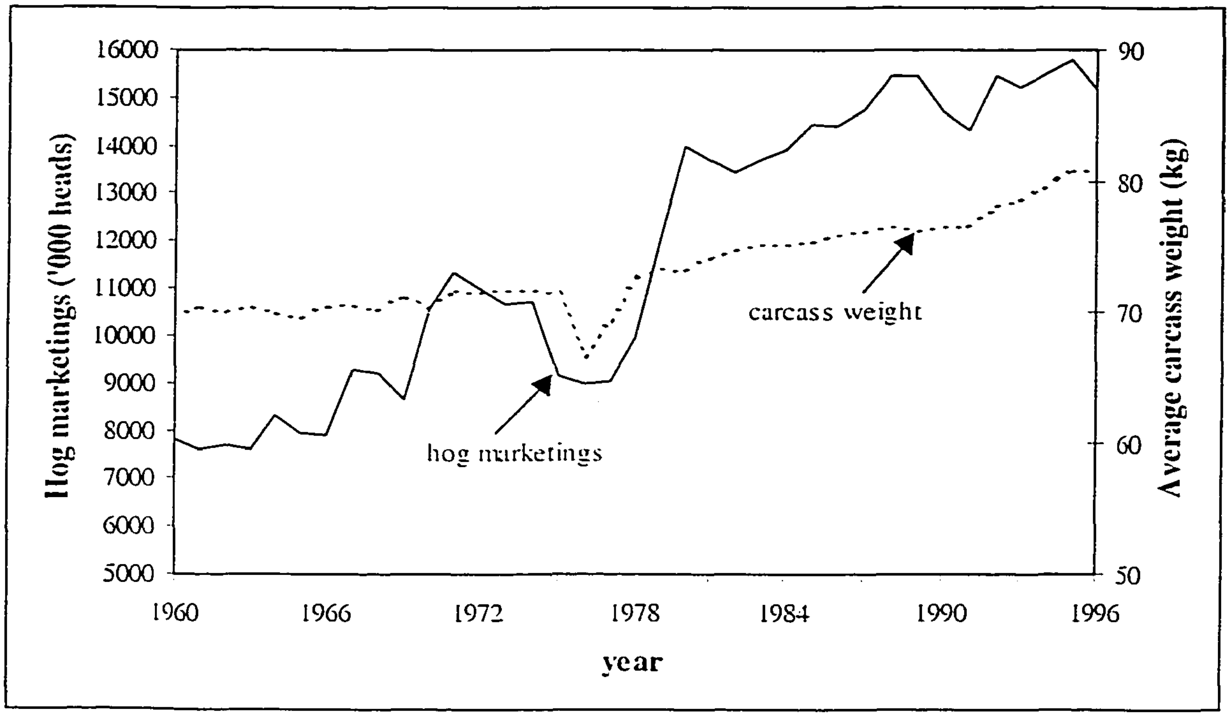
Future research on estimation of western Canadian commodity supply functions may improve the present study in a number of ways. First, it may be desirable to expand the number of commodities for study. Though the five commodities examined in the present study are considered to be major commodities, several other commodities are increasingly becoming popular, particularly 'speciality crops.' Second, the specification and inclusion of input demand functions for agricultural inputs such as chemicals, machinery, and labour may improve the specification and estimation of the models overall.

Figure 2.1: Canadian Slaughter Cattle Numbers and Average Carcass Weight (1960 to 1997)



Source: Agriculture and Agri-Food Canada. Livestock Market Review.

Figure 2.2: Canadian Slaughter Hogs Numbers and Average Carcass Weight (1960-1997)



Source: Agriculture and Agri-Food Canada. Livestock Market Review.

Table 2.1: Farm Sector Variables: Definition and Sources of Data (1960-1997)[1]

Variable	Definition	Source
Wheat production	Product of yield per hectare and area harvested in hectares.	CANSIM D216079 & D216083
Barley production	Product of yield per hectare and area harvested in hectares.	CANSIM D216204 & D216208
Canola production	Product of yield per hectare and area harvested in hectares.	CANSIM D216577 & D216581
Slaughter cattle production[2]	Cold dressed weight equivalent of slaughter cattle.	*Livestock Market Review* and CANSIM D226062
Slaughter hogs production[2]	Cold dressed weight equivalent of slaughter hogs.	*Livestock Market Review* and CANSIM D226377
Farmland Price	Farmland values	Farm Credit Corporation. Regina (Saskatchewan)
Wheat acreage	Area seeded in hectares.	CANSIM D216055 & D216059
Barley acreage	Area harvested in hectares.	CANSIM D216183 & D216187
Canola acreage	Area seeded in hectares.	CANSIM D216565 & D216569
Summer-Fallow	Summer-fallow areas in the prairie provinces.	CANSIM D216740
Tame Hay	Area seeded in hectares.	CANSIM D216635 & D216639
Beef cattle inventory	Total beef cattle numbers from annual livestock surveys.	D226005, D226008, D226014, D226017, D226023, D226026, D226032, D226035
Pig inventory	Total number of pigs from annual livestock surveys.	D236796, D236782, D236810, D236824
Wheat price	1 CWRS Final realised price ($)	Canadian Grain Council
Barley price	1 CW Final realised price ($)	Canadian Grain Council

Continued on next page

Table 2.1 continued

Variable	Definition	Source
Canola price	Weighted average price (see Appendix 2a)	CANSIM D216583 & Canadian Grain Council
Slaughter cattle price[3]	Weighted average price (Lethbridge / Southern Alberta)	*Livestock Market Review*
Slaughter hogs price[3]	Weighted average price (Edmonton / Alberta)	*Livestock Market Review*
Farm input price index	Aggregate input price index for western Canadian agriculture	CANSIM D641800
Interest rate	90-day commercial paper rate	Bank of Canada
Exchange rate	The equivalent of Canadian dollar to one American dollar	Bridge Information Systems, Chicago.
Corn price	No. 2 Yellow, Cash Basis – Chicago	Bridge Information Systems, Chicago.
Soybeans	No. 1 Yellow, Cash Basis – Central Illinois	Bridge Information Systems, Chicago.

1 The data series are presented in Appendix 2d.

2 Total Canadian beef (pork) production divided by total Canadian slaughter cattle (hogs) gives the average weight per animal. Beef (pork) production in Western Canada is obtained by multiplying the average weight per animal by total slaughter cattle (hogs) in Western Canada.

3 Slaughter cattle (hog) prices are quoted in $/cwt. (100 lb. weight). This is converted into $/tonne.

Table 2.2: Unit Root Tests

Variable	Test statistic	Number of lags	Variable	Test statistic	Number of lags
Wheat production	-2.62	2	Canola/cattle price ratio	-2.11	5
Barley production	-2.79	2	Hog/cattle price ratio	-2.42	2
Canola production	-1.26	5	Hog price	-1.95	3
Cattle production	-1.40	0	Wheat/hog price ratio	-3.05	4
Hog production	-3.45*	0	Barley/hog price ratio	-2.64	5
Land price	-3.58*	1	Canola/hog price ratio	-3.34*	2
Wheat price	-1.71	2	Cattle/hog price ratio	-2.37	2
Barley/wheat price ratio	-2.79	5	Wheat acreage	-2.36	0
Canola/wheat price ratio	-2.72	5	Barley acreage	-2.71	0
Cattle/wheat price ratio	-2.21	2	Canola acreage	-2.81	2
Hog/wheat price ratio	-3.25*	2	Fallow	-2.23	1
Barley price	-1.98	3	Tame hay	-2.40	0
Wheat/barley price ratio	-2.87	5	Cattle inventory	-2.36	1
Canola/barley price ratio	-2.62	5	Hog inventory	-2.84	2
Cattle/barley price ratio	-2.22	5	Interest rate	-1.68	0
Hog/barley price ratio	-3.41*	2	Wheat price	-2.36	4
Canola price	-1.71	2	Barley price	-1.00	4
Wheat/canola price ratio	-2.71	5	Canola price	-2.00	2
Barley/canola price ratio	-2.52	5	Cattle price	-1.03	2
Cattle/canola price ratio	-2.18	5	Hog price	-0.86	3
Hog/canola price ratio	-3.33*	2	Wheat acreage	-3.38*	0
Cattle price	-1.93	0	Barley acre/wheat acre	-2.33	0
Wheat/cattle price ratio	-2.57	0	Canola acre/wheat acre	-2.76	2
Barley/cattle price ratio	-2.21	5	Fallow acre/wheat acre	-2.87	1
			Hay acre/wheat acre	-3.36*	0

* Indicates the value is significant at the 10% level therefore, the null hypothesis of unit root is rejected.
Note: asymptotic critical value at 10% significance is –3.13.

Table 2.3: Estimated Coefficients of the Commodity Supply Response Models

	Dependent Variable					
	Wheat Production	Barley Production	Canola Production	Cattle Production	Hog Production	Farmland Value
Intercept	0.238	0.097	1.075[b]	1.957[a]	1.110	1.101[a]
Wheat price	0.037	0.203	-0.054	-0.031	0.294[b]	0.419[b]
Barley price	0.203	0.183	-0.151	0.023	0.240	0.005
Canola price	-0.054	-0.151	0.212[b]	-0.152	0.209	-0.007
Cattle price	-0.031	0.023	-0.152	0.320[a]	-0.037	0.296[a]
Hog price	0.294[b]	0.240[b]	0.209	-0.037	0.124	-0.062
Wheat acreage	0.589	-0.247	-0.255	-0.609[a]	-0.532	-1.753
Barley acreage	0.271	1.170[a]	0.099	-0.241[a]	0.350	0.581[a]
Canola acreage	-0.231[b]	-0.171[a]	0.842[a]	-0.221[a]	-0.055	0.221
Summer-Fallow	-0.869[a]	-0.684[a]	-0.800[a]	-0.922[a]	-0.712	1.139
Hay acreage	0.839[b]	0.563[a]	0.051	0.347	0.843	-1.114[b]
Cattle inventory	-0.101	-0.031	0.097	0.658[a]	-0.982[a]	0.724[a]
Pig inventory	-0.282[b]	-0.309[a]	-0.185[b]	-0.061	0.148	-0.576[a]
Interest Rate	0.011	0.007	-0.005	-0.010[b]	-0.009	0.008
R-square	0.86	0.96	0.99	0.94	0.88	0.96
Variance of estimates	0.010	0.003	0.005	0.004	0.019	0.007
D-W statistic	1.9	2.3	2.2	1.1	1.9	1.5

[a] indicates asymptotic significance at the 5% level.
[b] indicates asymptotic significance at the 10% level.

Table 2.4: Estimated Measures of Partial Supply Elasticities[1]

	Wheat Production	Barley Production	Canola Production	Cattle Production	Hog Production
with respect to					
Wheat price	0.449	0.203	-0.054	-0.031	0.294[b]
Barley price	0.203	0.498[a]	-0.151	0.023	0.240[a]
Canola price	-0.054	-0.151	0.064	-0.152	0.209
Cattle price	-0.031	0.023	-0.152	0.123	-0.037
Hog price	0.294[b]	0.240[b]	0.209	-0.037	0.830[a]
Wheat acreage	0.589	-0.247	-0.255	-0.609[a]	-0.532
Barley acreage	0.271	1.170[a]	0.099	-0.241[a]	0.350
Canola acreage	-0.231[b]	-0.171[a]	0.842[a]	-0.221[a]	-0.055
Summer Fallow	-0.869[a]	-0.684[a]	-0.800[a]	-0.922[a]	-0.712
Hay acreage	0.839[b]	0.563[a]	0.051	0.347	0.843
Cattle inventory	-0.101	-0.031	0.097	0.658[a]	-0.982[a]
Pig inventory	-0.282[b]	-0.309[b]	-0.185[b]	-0.061	0.148
Interest Rate	0.011	0.007	-0.005	-0.010	-0.009

[1] Partial elasticity measures express the change in supply induced by a change in price holding allocatable land constant.
[a] indicates asymptotic significance at the 5% level.
[b] indicates asymptotic significance at the 10% level.

Table 2.5: Comparison of Partial Supply Elasticity Estimates with Those from Selected Studies of Western Canadian Agriculture

	This Study	Coyle (1993b)	Meilke & Weersink (1991)	Horbulyk (1990)	Coleman & Meilke (1988)
Sample period	1960-1997	1961-1984	1972-1988	1983-1987[a]	1972-1982[b]
Commodity					
Wheat	0.449	0.159	0.617		
Barley	0.498	0.273	0.788		
Canola	0.064	0.448	1.546		
Cattle	0.123			1.998	0.24
Hogs	0.830				1.36
Wheat / Barley price	0.203	-0.096	-0.196		
Wheat / Canola price	-0.054	-0.006	-0.213		
Barley / Wheat price	0.203	-0.062	-0.430		
Barley / Canola price	-0.151	-0.253	-0.209		

[a] Data are cross sectional.
[b] Data are quarterly.

Table 2.6: **Estimated Measures of Total Supply Elasticities**[1]

With respect to	Wheat Production	Barley Production	Canola Production	Cattle Production	Hog Production
Wheat price	1.058	0.446	0.293	0.460	0.668[b]
Barley price	0.210	0.741[a]	0.196	0.514[b]	0.614[b]
Canola price	-0.064	0.092	0.411	0.372	0.583
Cattle price	0.400	0.266	0.195	0.614[b]	0.338
Hog price	0.203	0.483[b]	0.556[b]	0.488[b]	1.204[a]

[1] Total elasticity measures express the change in supply induced by a change in price as well as a change in allocatable land due to the price change.

[a] indicates asymptotic significance at the 5% level.

[b] indicates asymptotic significance at the 10% level.

Table 2.7: Chi-squared Test Results for Non-Jointness in Production

Test of non-jointness (independence in production) includes

	all 5 enterprises[a]	Only crop enterprises[b]	Only livestock enterprises[c]	barley and hogs[d]
	$\chi^2_{df=13}$ statistic	$\chi^2_{df=11}$ statistic	$\chi^2_{df=2}$ statistic	$\chi^2_{df=3}$ statistic
Equation				
Wheat Production	143.48	123.41		
Barley Production	328.81	260.00		140.89
Canola Production	575.77	526.07		
Cattle Production	105.45		2.56	
Hog Production	50.65		2.11	11.70
Test Outcome	Independence in production is rejected in each equation	Independence in production is rejected in each equation	Independence in production is not rejected in each equation	Independence in production is rejected in each equation

[a] the critical values at the 5% level of significance for $\chi^2_{df=13}$ = 22.362
[b] the critical values at the 5% level of significance for $\chi^2_{df=11}$ = 19.675
[c] the critical values at the 5% level of significance for $\chi^2_{df=3}$ = 7.815
[d] the critical values at the 5% level of significance for $\chi^2_{df=2}$ = 5.991.

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Appendix 2a: Canola Price Series

Statistics Canada (CANSIM) provided a weighted average price per tonne for the period 1960 to 1984 (P_{c1}) while the Canadian Grains Council (Canadian Grains Industry Statistical Handbook) provided cash prices (Winnipeg) from 1972 to 1996 (P_{c2}). The overlapping period between the two series is 1972 to 1984 (13 data points). Ordinary Least Squares (OLS) regression of P_{c2} on P_{c1} through the origin produced the following results:

$$\hat{P}_{c2} = \underset{(0.01658)}{1.1108} P_{c1} \qquad R^2 = 0.9419$$

Standard error of the estimate is reported in brackets.

The estimated coefficient is multiplied by the P_{c1} series from 1960 to 1971 to generate an estimated price series that is consistent with the P_{c2} series. The generated series (1960 to 1971) and the P_{c2} series (1972 to 1996) are used in the study.

Appendix 2b: Elasticity Formulations

Due to the wide variation in the values of variables, all variables were divided by their respective mean values. Consequently, the mean values of data 1960 to 1997 are unity. Using equation (2.18), the partial own-price elasticity of supply is calculated as:

$$\frac{\partial q_i}{\partial w_i}\frac{w_i}{q_i} = \Xi_{ii} = \alpha_i + \sum_j \alpha_{ij} \qquad i \neq j$$

The partial cross-price elasticity of supply is calculated as:

$$\frac{\partial q_i}{\partial w_j}\frac{w_j}{q_i} = \Xi_{ij} = \alpha_{ij} \qquad i \neq j$$

The partial elasticity of supply with respect to reallocation of farmland is calculated as:

$$\frac{\partial q_i}{\partial z_k}\frac{z_k}{q_i} = \Xi^{z}_{ik} = \delta_{ik}$$

The partial elasticity of supply with respect to changes in quasi-fixed variables is calculated as:

$$\frac{\partial q_i}{\partial d_i}\frac{d_i}{q_i} = \Xi^{d}_{ii} = \lambda_{ii}$$

Using equations (2.12) and (2.19), the total elasticity of supply is calculated as:

$$\frac{\partial q_i(w,z,d)}{\partial w_j}\frac{w_j}{q_i} = \frac{\partial q_i}{\partial w_j}\frac{w_j}{q_i} + \sum_i \sum_k \frac{\partial q_i}{\partial z^i_k}\frac{z^i_k}{q_i} \left(\frac{\partial z^i_k}{\partial w_j}\frac{w_j}{z^i_k}\right)$$

$$\Xi^T_{ij} = \Xi_{ij} + \sum_i \Xi^z_{ik} \quad {}^{\delta_{kj}}\!/_{\beta_{kl}}$$

Total Elasticity of Supply	=	Partial Price Elasticity of Supply	+	Partial Elasticity of Supply with respect to Farmland Allocations	Elasticity of Acreage Allocation with respect to Price

Appendix 2c: Formulations for Testing Non-jointness in Production[11].

1. Test for non-jointness in the production of all five commodities involves testing the following in each supply equation (2.18);

$$\alpha_{ij} = \delta_{ik} = \beta_{kl} = 0 \qquad \forall \quad i \neq j; \quad k \neq l$$

2. Test for non-jointness in production of grains/oilseed involves testing the following in equation (2.18) relating to the supply of wheat, barley and canola;

$$\alpha_{ij} = \delta_{ik} = \beta_{kl} = 0$$

$$\text{for} \quad i, j = 1,2,3; \quad k, l = 1,\ldots,5; \quad i \neq j; \quad k \neq l$$

3. Test for non-jointness in production of livestock involves testing the following in equation (2.19) relating to the supply of cattle and hogs;

$$\alpha_{ij} = 0 \qquad \text{for} \quad i, j = 4,5; \quad i \neq j$$

4. Test for non-jointness in production of barley and hogs involves testing the following in equation (2.18) relating to the supply of barley and hogs;

$$\alpha_{ij} = \delta_{ik} = \beta_{kl} = 0 \qquad \text{for} \quad i, j = 2,5; \quad k, l = 2; \quad i \neq j$$

[11] The index i,j = 1,...,5 represents the production of wheat, barley, canola, cattle and hogs respectively; k,l = 1,...,5 represents hectares of wheat, barley, canola, tame hay and summer fallow respectively; and t,u = 1,...,3 represents cattle inventory, hog inventory and interest rate respectively.

Appendix 2d: Data Series Used for the Farm Sector Model

Year	Wheat acreage	Wheat production	Barley acreage	Barley production	Canola acreage	Canola production	Cattle numbers	Hog numbers	Cattle production	Hog production	Summer fallow	Tame hay acreage
1960	9322800	13109300	2727500	4115600	308800	252200	2189	4571	320247	202179	10883	1838000
1961	9253300	6749500	2194700	2358500	287500	254500	2297	5011	373637	196728	11274	2003000
1962	9269800	13148200	2095300	3507500	150200	132900	2413	3898	335972	188124	11208	2070000
1963	10141200	17821000	2444600	4690600	193400	189500	2661	4108	330390	153988	11081	2072000
1964	11099600	14944800	2155700	3502200	320100	300000	2907	4804	375894	187084	10748	2111000
1965	10963300	16841700	2384500	4518100	580700	512600	2999	4112	469095	191150	10794	2208000
1966	11424400	21285700	2897700	6168600	617100	585100	2949	4497	483825	172043	10208	2305000
1967	11479900	15129200	3148800	5177700	661700	563600	2901	5005	466346	209559	10501	2222000
1968	10783900	16006500	3439800	6688000	427300	441400	2795	4824	494215	217616	10789	2114000
1969	8658700	15578500	3630800	7669400	818200	760300	2913	5493	423239	199200	11655	2240000
1970	3646400	6354700	3835800	8447600	1648700	1646500	3219	7457	419001	258761	14933	2702000
1971	6766100	12446200	5466300	12571900	2161400	2165900	3524	11258	425335	338663	10612	2518000
1972	7184500	12031800	4876700	10813200	1342700	1317700	3835	13716	455377	307532	11737	2701000
1973	8444500	14292600	4662800	9797600	1297100	1223700	3998	13481	443835	297048	10725	2785000
1974	7576300	11144700	4600800	8391300	1278800	1163500	4200	11440	477138	290533	11250	2933000
1975	7772300	13833800	4284900	9049900	1829200	1839200	4432	8435	555584	201185	11048	2913000
1976	9455300	19654900	4168700	10087700	719500	836900	4349	8523	613370	167838	10764	3263000
1977	8974400	17377300	4585800	11380600	1452800	1973100	4012	8919	629387	182879	10967	3211000
1978	8749300	17336000	4197700	9848400	2524000	3497100	3758	9432	558667	201398	10239	3151000
1979	9036400	14380600	3532600	7899300	3407500	3411100	3591	11100	501291	241303	10400	3091000
1980	9535000	16192100	4592900	10649900	2080100	2483400	3629	12009	500259	290096	10481	2999000
1981	10334900	20579100	5151100	12804400	1401400	1848500	3561	11701	532406	283752	9510	2910000
1982	10746600	22797500	4765100	12773400	1768500	2218100	3574	11434	571517	277070	9308	2931000
1983	11790000	22498000	3958000	9286000	2307000	2586000	3455	12368	567096	294217	9045	3024000
1984	10921000	17609000	4196000	9178000	3060000	3391000	3390	13924	579402	347304	8417	3131000
1985	11178000	20282000	4361000	11045000	2761000	3453000	3316	13734	577971	362235	8296	3160000
1986	11506800	25251000	4374600	13150600	2592000	3640200	3206	13756	572147	118544	8297	3250400
1987	10633100	20384000	4548700	12580100	2598100	3690000	3131	15343	554387	373990	8620	3537000
1988	10094900	12413000	3773700	9198800	3692800	4191100	3287	16951	625901	428396	8822	3702900
1989	10633100	19201000	4340200	10542200	2901700	3184300	3394	16511	637682	441663	8295	3638100
1990	11483000	26046000	4154000	12229600	2509100	3222800	3508	15780	646572	419683	8134	3771700
1991	11877595	26450900	4117908	10474800	3114485	4178800	3613	16748	613554	399313	7781	3747126
1992	12472300	25161200	3403400	9633200	3221300	3842900	3947	17456	717708	476097	7319	4350300
1993	11176800	22917800	4180400	11885500	4152100	5486300	4123	17109	725209	475205	7122	4316000
1994	8235300	16776900	3992300	10767500	5774800	7187100	4186	17720	764644	491623	6799	4560800
1995	8761100	18671900	4338100	12112000	5309600	6368400	4515	19021	801818	492738	6779	4457600
1996	9914700	23949800	4921000	14623400	3514800	5010900	4756	18655	954172	518648	6192	4287800
1997	8945400	18812300	4692300	12471300	4874400	6327700	4669	18885	930998	526393	5645	4251200

Continued on next page

Appendix 2e: Data Series Used for the Farm Sector Model

Year	Crop land prices	Wheat prices	Barley prices	Canola prices	Cattle prices	Hog prices	Input Index	CPI	US corn price	US soy price	Interest rate
1960	11.33	57.69	36.74	79.98	417.04	456.42	21.05	18.5	115.79	215.75	4
1961	11.74	63.93	48.69	87.75	420.35	526.55	22.6	18.7	113.4	268.37	3.37
1962	12.55	60.99	43.17	99.97	481.19	561.95	24.1	18.9	113.01	249.88	4.38
1963	14.16	71.39	43.17	123.3	465.71	561.95	25	19.2	125.51	267.56	4.01
1964	16.19	68.01	50.43	134.41	428.1	505.53	24.9	19.6	125.41	267	4.2
1965	19.02	72.24	54.43	117.74	435.84	.605.09	25.8	20	130.24	282.17	5.02
1966	21.85	72.05	55.07	121.08	493.36	710.18	27.2	20.8	136.96	312.77	6.27
1967	25.09	65.66	55.48	94.42	523.23	568.58	27.4	21.5	129.62	280.15	5.85
1968	26.71	60.99	46.3	89.97	523.23	586.28	28.3	22.4	113.88	266.17	6.82
1969	24.69	60.81	44.55	112.19	594.03	736.73	29.4	23.4	123.47	259.7	7.85
1970	24.28	60.66	38.21	114.41	620.58	628.32	29.6	24.2	137.77	276.86	7.34
1971	23.88	58.64	41.8	105.53	639.38	470.13	30.7	24.9	138.99	310.87	4.51
1972	24.28	79.15	37.2	160.5	680.78	1000	32.8	26.1	130.67	348.49	5.1
1973	28.73	168.21	119.06	279.76	877.21	1104.42	38.1	28.1	219.72	703.69	7.45
1974	36.42	164.39	107.05	318.95	846.68	992.48	44.2	31.1	322.15	675.03	10.51
1975	47.35	146.27	104.06	226.8	707.52	1437.31	50	34.5	291.27	542.37	7.94
1976	57.47	117.15	91.5	282.13	675.22	1329.62	53.6	37.1	271.27	578.61	9.17
1977	65.56	120.3	88.39	295.94	727.65	1265.77	55	40	224.37	700.56	7.48
1978	80.13	160.53	91.08	304.77	1089.6	1529.62	62.2	43.6	233.35	650.94	8.83
1979	97.53	196.43	107.47	309.04	1517.92	1429.81	72.9	47.6	265.12	706.29	12.07
1980	134.36	222.12	146.55	329.35	1402.43	1268.24	80.3	52.4	300.79	696.19	13.15
1981	154.59	199.62	131.07	325.19	1330.31	1503.73	92.4	58.9	315.57	697.74	18.33
1982	167.14	192.34	110	306.99	1260.4	1814.15	95.6	65.3	255.88	585.82	14.15
1983	163.90	193.98	138.02	455.44	1305.09	1542.88	95.7	69.1	326.28	689.99	9.45
1984	159.04	186.37	131.3	386.04	1365.49	1517.5	98.1	72.1	327.51	695.83	11.19
1985	144.47	160	110	301.4	1261.5	1441.35	98.7	75	268.5	546.35	9.56
1986	134.36	130	80	239.7	1319.03	1729.43	100	78.1	210.74	506.38	9.16
1987	120.60	134.02	74.08	303.35	1339.82	1695.08	98.7	81.5	171.83	515.11	8.38
1988	115.74	197.14	124.23	337.4	1325.44	1270.56	101.7	84.8	246.79	738.33	9.67
1989	115.74	172.11	124.38	303.72	1307.74	1266.54	106.2	89	259.11	664.08	12.21
1990	114.93	135	90	287.72	1749.78	1543.27	108.6	93.3	257.85	585.69	13.03
1991	107.24	134.14	107.59	274.85	1677.88	1366.58	106.3	98.5	253.39	563.71	8.91
1992	103.20	156.82	102.46	321.61	1648.45	1239.06	104.9	100	247.44	562.66	6.74
1993	102.39	164.01	99.94	391.38	1857.08	1458.04	109.8	101.8	242.71	613.16	4.97
1994	109.67	195.59	101.94	412.18	1901.99	1365.65	113.9	102	257.96	612	5.66
1995	121.00	254.16	205.49	433	1833.85	1474.48	119.7	104.2	282.96	599	7.22
1996	127.07	208.2	150.97	441.1	1734.96	1823.31	123.9	105.8	396.19	744.97	4.35
1997	128.29	190.76	121.02	419.92	1858.41	1793.1	126.2	107.6	282.66	755	3.61

3. ANALYSIS OF DOMESTIC DEMAND FOR FARM OUTPUT

3.1 Introduction

Initiatives taken by the government on value adding activities are focussed at encouraging and promoting projects that contribute to the economic development of the agricultural industry. Government initiatives on value adding include funding programs that encourage research and development into the commercialization of value-added products. With such programs, it is hoped that the food-processing sector will undertake structural adjustments that may eventually result in increased utilization of primary agricultural commodities.

Agricultural and food-processing industries in Canada and the United States have become increasingly concentrated, often resulting from mergers and acquisitions (Green 1985). The trend toward fewer and larger firms has continued since the 1960s, which could raise concerns about potential market power and its exploitation. In particular, if increasing concentration allows firms to exploit the domestic market for farm commodities, then farmers will be affected if the food processing firms are able to use their power to hold commodity prices at artificially low levels. However, the efficiency of increasingly large plants in the food-processing industries when plant size is determined by production structure characteristics such as cost economies and technical change have been pointed out (Hazeldine 1991; Goodwin and Brester 1995; Holloway and Goddard 1988: Paul 199b). In these circumstances increased import and export competition may modify market power. In Canada, a significant proportion of primary agricultural products particularly grains and oilseeds is exported, suggesting that, with export competition, food-processing firms may not be able to exercise any market power in the domestic market for farm outputs.

This portion of the thesis examines aggregate demand of the processing sector for wheat, barley, canola, slaughter cattle and hogs to assess potential market power exploitation. An alternative index for measuring industry-wide market power is developed. The procedure used here differs from previous studies in that conjectural marginal input cost is explicitly incorporated into a profit function allowing a system of factor demand and output supply equations to be estimated. With this procedure and sufficient data, policy analyses can be conducted by assessing the conduct of the industry over time in response to certain changes. This framework is applied to four Standard Industrial Classification (SIC) food-processing industries in Canada including the meat and meat products (excluding poultry) industry, the cereal grain flour industry, the livestock feed industry and the vegetable oil (excluding corn oil) industry. These are the major food processing industries for Western Canadian agricultural outputs.

The following section reviews some of the approaches that have been utilized in previous studies to assess market power in the market for farm output. This is followed by an outline of the theoretical foundation of the model used here to measure the degree of oligopsony power. Duality theory is applied with the incorporation of a profit function that explicitly incorporates a price “mark-down” factor to assess possible non-competitive behaviour in the market for farm outputs. The models are applied to aggregate annual data from four Canadian food industries for the period 1974 to 1996. The results and a discussion of these are then presented and some conclusions are drawn from this component of the study. The final section summarizes the findings of the study and discusses limitations of the study.

3.2 Review of Past Derived Demand Studies

A common approach adopted in studies that examine derived demand relationships and market power involves the application of the theory of the firm. A behavioural assumption involving maximization of short run profits or minimization of costs is made for the processing firm. From the solution of the first-order conditions for the maximization or minimization problem, output supply and input demand schedules for the marketing firm are obtained. This approach has been applied in many studies to examine demand relationships under different market structures. Most of these studies analyse a firm's conduct through the estimation of conjectural elasticities. These are measures of the firm's expectation of the percentage change in industry output (input) in response to its own output (input) change. Unfortunately, panel data on firm level input and output are frequently unavailable due to confidentiality concerns. This limitation has led analysts to assume that conjectural elasticity measures are identical across firms. This particular assumption allows the application of conjectural elasticity measures to the industry level in the form of indices of market power in output and input markets (Appelbaum 1982; Azzam and Pagoulatos 1990). However, changing consumer preferences, corporate mergers, strategic alliances of firms and acquisitions of firms have changed the structure of the food industry and consequently, the aggregate values of the conjectural elasticities can be expected to have changed.

Appelbaum (1979, 1982) used the theory of the firm to provide a general framework to examine non-competitive behaviour in a processors' output market. The framework developed by Appelbaum has been extended to the processors' input market (e.g., Azzam and Pagoulatos 1990; Chen and Lent 1992; Durham and Sexton 1992; Huang and Sexton 1996; Schroeter and Azzam (1991); Sexton 1990; Wann and Sexton 1992).

In a perfectly competitive market structure, processing firms are assumed to be price takers in the market for farm commodities and have no influence in setting purchase prices. The assumption of a perfectly competitive market structure has sometimes been applied in welfare analyses of the impacts of agricultural policies. Studies of derived demand that have assumed perfectly competitive farm commodity markets include Dunn and Heien (1985); Martin and Alston (1994); Mullen et al. (1988); Kinnucan et al. (1996); and Wahl et al. (1992).

If agricultural markets are not perfectly competitive, the welfare implications may differ from the perfectly competitive structure. Consequently, some studies have examined derived demand relationships under an assumption of imperfect competition in the processors' input markets (e.g., Chen and Lent 1992; Durham and Sexton 1992; Huang and Sexton 1996; Hyde and Perloff 1994; Just and Chern 1980; Sexton 1990). Further extensions of this general modelling framework are found in the literature. For example, Azzam and Pagoulatos (1990), Dryburgh and Doyle (1995), Schroeter (1988), Schroeter and Azzam (1991), and Wann and Sexton (1992) have investigated non-competitive behaviour in both the output and input markets.

Some of the studies cited above focus on investigating comparative statics in imperfect competitive market situations, while others investigate the implications for market equilibrium of exogenous shocks in supply and demand. Issues that have been examined in the context of non-competitive markets include the impact of agricultural policy, government programs, research, advertising and promotion. The implications of policy or exogenous factors are not the focus of this part of the study. However, results obtained from the models will be used to simulate the likely impact on the farm sector of value adding initiatives in the processing sector.

3.3 Theoretical Framework

3.3.1 Preliminary Outline

It is postulated that the behaviour of a firm is determined by its production technology and by the economic environment in which it operates, both of which act as constraints on the firm's decision making. Assuming profit maximization for a primary processing industry that is producing a retail good x, using a homogenous technology g(.), the production function for the industry may be expressed as:

$$x = g(q, v, z) \tag{3.01}$$

where $x=\sum x^j$, is the sum of all outputs produced by the j firms in the industry; q is a vector of farm commodity inputs; v is a vector of marketing inputs; and z is a vector of quasi-fixed factors.

For simplicity, assume there is only one farm commodity and one marketing input. The short run variable cost c, for the j^{th} firm is expressed as:

$$c^j = wq^j + mv^j \tag{3.02}$$

where q^j and v^j are the farm commodity and marketing input used by the j^{th} firm in the production process and w and m are the respective prices. If p is the price of the industry output faced by all firms in the market, then in the short run (when z is fixed), the profit function for the j^{th} firm is:

$$\Pi^j(p,w,m,z^j) = \max[px^j - wq^j - mv^j - r'z^j; \quad g^j(q^j,v^j,z^j)] \qquad (3.03)$$

where r is the price of the quasi-fixed input. Equation (3.03) is an expression of the maximum level of profit (i.e., revenue minus cost) given the exogenous factors and the fixed input. Given standard assumptions for the underlying technology, the profit function of equation (3.03) has the properties of being positive (monotonicity), non-decreasing in p, non-increasing in w, convex and continuous in p and w[12]. Consequently, the first-order conditions (*Hotelling's lemma*) for (3.03) provide a system of short run output supply and factor demand equations for the firm expressed as:

$$x^j = \frac{\partial \Pi^j(p,w,m,z^j)}{\partial p} \qquad (3.04)$$

$$q^j = -\frac{\partial \Pi^j(p,w,m,z^j)}{\partial w} \qquad (3.05)$$

$$v^j = -\frac{\partial \Pi^j(p,w,m,z^j)}{\partial m} \qquad (3.06)$$

where x^j is output supply function for firm j; q^j is farm commodity input demand function for firm j; and v^j is marketing input demand function for firm j. An assumption in the above formulation is that firms in the industry are price takers in the output and input markets. The properties of the profit function of equation (3.03) imply that:

[12] The assumption is that the input requirement set is convex, closed and non-empty for all x>0 (i.e., all input combinations capable of producing output level x).

$$\frac{\partial x^j}{\partial p} \geq 0; \qquad \frac{\partial q^j}{\partial w} \leq 0; \qquad \text{and} \qquad \frac{\partial v^j}{\partial m} \leq 0 \tag{3.07}$$

$$\frac{\partial x^j}{\partial w} = -\frac{\partial q^j}{\partial p}; \qquad \frac{\partial x^j}{\partial m} = -\frac{\partial v^j}{\partial p}; \qquad \text{and} \qquad \frac{\partial q^j}{\partial m} = \frac{\partial v^j}{\partial w} \tag{3.08}$$

The expressions in (3.07) are the direct consequences of the convexity of the profit function and the expressions in (3.08) are reciprocity or symmetry relationships. These expressions represent a set of conditions on smoothly differentiable supply and factor demand functions that ensure these functions can be "integrated" to capture the technology underlying the profit function that generated them (Chambers 1988, p. 131). These expressions or conditions are useful for validating estimation models.

3.3.2 *Modelling Non-Competitiveness*

Non-competitive behaviour is characterized by firms possessing some control in determining their input and/or output prices. For example, firms having oligopsony power are able to influence their input prices. The extent of influence depends on the conjectures of other firms in the industry. In modelling oligopsony power, these conjectures are taken into consideration.

Consider the situation of the processing firm that has some influence (i.e., market power) over prices for farm commodities but is a price taker in the markets for its own output and other non-farm inputs. The objective function (3.03) becomes:

$$\Pi^j(p,w,m,z^j) \quad = \quad \max[px^j - w(q)q^j - mv^j - r'z^j] \tag{3.09}$$

The first order condition for profit maximization with respect to the farm commodity input is:

$$p\frac{\partial x^j}{\partial q^j} = w + q^j \frac{\partial w(q)}{\partial q}\frac{\partial q}{\partial q^j} \quad (3.10)$$

The expression on the left side of (3.10) is the value of marginal product (VMP) for farm commodity input. The term on the right side is the effective marginal cost (EMC) to the firm (an oligopsonist). Using algebraic manipulation (see Appendix 3a), the EMC term can be expressed in elasticities as follows:

$$p\frac{\partial x^j}{\partial q^j} = w(1 + \frac{\theta^j}{\varepsilon}) \quad (3.11)$$

where θ^j is the firm's conjectural elasticity in the farm commodity market; and ε is the price elasticity of the farm commodity supply. θ^j shows the j^{th} firm's perception of the percent change in the purchases by all firms in the industry in reaction to a one percent change in its own purchases. Thus, θ^j with values in the [0,1] interval can be interpreted as an index of market power in the affected farm commodity. This parameter is comparable to Appelbaum's (1982) conjectural elasticity term for the output market. Chen and Lent (1992) refer to the right side of (3.11) as the processor's conjectural marginal input cost (CMIC) and suggest that this is useful for testing the degree of monopsony/oligopsony power held by the processor. Azzam and Pagoulatos (1990) suggest that in equilibrium θ^j is invariant across firms, that is:

$$\theta^1 = \theta^2 = ... = \theta^n = \theta \quad (3.12)$$

Azzam and Pagoulatos (1990) also suggest that the ratio θ^j/ε, is an industry–wide index of oligopsony power in the farm commodity market. The index represents the degree to which processing firms can set input price below the marginal product i.e., price "mark-down". With observations for the farm commodity price w, the conjectural marginal input cost can be estimated with knowledge of the market elasticity ε. From equation (3.11) if the index equals zero, a perfectly competitive market exists for the affected farm commodity. If the index does not equal zero, the farm commodity market is not perfectly competitive. By rearranging the expression in (3.11), Hyde and Perloff (1994) suggest that the price "mark-down" can be expressed as:

$$\mu_q = \frac{p}{w}\frac{\partial x^j}{\partial q^j} = (1+\frac{\theta^j}{\varepsilon}) \tag{3.13}$$

where μ_q is the price "mark-down." If μ_q=1, the industry-wide index equals zero and the value of marginal product of the processor's farm commodity input equals the farm commodity price. If $\mu_q \neq 1$, the index is not zero. The expression for price "mark-down" (3.13) can be expressed alternatively as (see Appendix 3b):

$$\mu_q = \frac{\xi_q}{\varpi_q} \tag{3.14}$$

where ξ_q is the firm's elasticity of output with respect to the farm commodity input, and ϖ_q is the cost of the farm commodity input relative to value of supply (i.e., farm commodities input cost share of value of supply). From (3.13) the conjectural marginal input cost of the farm commodity input equals $w\mu_q$.

Appelbaum (1979) suggests ways that non-competitive behaviour may be incorporated into (3.03). Following Appelbaum, and substituting for *CMIC*, (=$w\mu_q$) the profit function for the oligopsonist has the form:

$$\Pi^j = \Pi^j[p, w, \mu_q, m, z^j] \tag{3.15}$$

The first-order conditions for profit maximization from (3.15) give the short run output supply, farm commodity input demand and marketing input demand functions respectively as:

$$x^j = \frac{\partial \Pi^j [p, w, \mu_q, m, z^j]}{\partial p} \tag{3.16}$$

$$q^j = -\frac{\partial \Pi^j [p, w, \mu_q, m, z^j]}{\partial w} \tag{3.17}$$

and

$$v^j = -\frac{\partial \Pi^j [p, w, \mu_q, m, z^j]}{\partial m} \tag{3.18}$$

The output supply and factor demand functions (3.16) to (3.18) are homogenous of degree zero in p and w, i.e., only relative price changes affect supply or demand. The second-order conditions of (3.15) are similar to (3.07) and (3.08) and are useful for validating (3.16) to (3.18).

Based on the development of these expressions, specification of a functional form for (3.15) allows us to derive estimable supply and demand functions to test for the significance of μ_q, the price "mark-down". Thus, we can test for non-competitive behaviour in the market for farm commodities.

3.3.3 *Aggregation Issues*

The model outlined above is a firm-level model. As is often the case in empirical work, firm-level data for prices and quantities are not available because of confidentiality restrictions. To apply the firm-level formulations to the industry, the common assumption that is applied in empirical work is linear aggregation of output and profits for the firms in the industry, that is:

$$x = \sum_{j=1}^{n} x^j \tag{3.19}$$

and

$$\Pi = \sum_{j=1}^{n} \Pi^j [p, w, \mu_q, m, z^j] \tag{3.20}$$

where x is the industry output and Π is the industry profit. Any functional form capable of incorporating (3.19) and (3.20) is a candidate for an industry profit function (Chambers 1988 p. 183). The first-order condition of (3.20) with respect to output price p, is:

$$\frac{\partial \Pi}{\partial p} = \sum_{j=1}^{n} \frac{\partial \Pi}{\partial \Pi^j} \frac{\partial \Pi^j}{\partial p} = \sum_{j=1}^{n} \frac{\partial \Pi^j}{\partial p} \quad \text{since} \quad \frac{\partial \Pi}{\partial \Pi^j} = 1 \tag{3.21}$$

Thus,

$$\frac{\partial \Pi}{\partial p} = \sum_{j=1}^{n} \frac{\partial \Pi^j}{\partial p} \quad \forall \quad j \tag{3.22}$$

The assumption of linear aggregation of output and profits across firms allows the firm-level formulation to apply to the industry. The problem with the aggregation assumption is that from the aggregate perspective, it is irrelevant which firm produces which units of output. Equation (3.22) implies that the sum of each firm's level of output equal aggregate output.

3.4 Application and Empirical Specifications

The formulation to assess imperfect competition outlined above is applied to each of the four food processing industries of meat and meat products (excluding poultry) industry, the cereal grain flour industry, the livestock feed industry and the vegetable oil (excluding corn oil) industry. The procedure outlined above differs from the cited previous studies in two major ways. First, the conjectural marginal input costs of farm commodity inputs are explicitly incorporated into the oligopsonist's profit function and a system of factor demand and output supply equations is estimated. None of the cited studies have estimated factor demand and output supply functions of the form (3.16) to (3.18). Most studies investigating market power use a variant of (3.10) and specify this as a behavioural function. For example, (3.10) may be specified as a factor demand function (e.g., Azzam and Pagoulatos 1990). A similar derivation for an oligopolist may be specified as a supply function (e.g., Schroeter 1988; Wann and Sexton 1992).

A second distinction of the approach discussed here is that the functions incorporate the oligopsonist's conjectural marginal input costs of farm commodity inputs into the profit function. This permits the evaluation of the direct effect of farm commodity input prices as well as the effect of any price "mark-down." This approach is particularly important because the existence of a price "mark-down" represents a depression of the price that farmers receive and this may result in resources being diverted away from the production of the affected farm commodity.

Now consider a firm producing any of the industrial products being considered, i.e., meat and products (excluding poultry), cereal grain flour, livestock feed, or vegetable oil (excluding corn oil). It is assumed that, for farm commodity input, the meat products industry uses cattle; the wheat flour industry uses wheat; the livestock feed industry uses barley; and the vegetable oil industry uses canola. In addition to farm commodity input, all firms are assumed to use labour, capital, and energy as other inputs. The profit function of the firm may be specified as a Translog profit function (Christensen et al. 1973) expressed as:

$$\left.\begin{aligned}\ln \Pi &= b_0 + b_x \ln p + b_q \ln w + b_q^{*} \ln \mu_q + b_v \ln m + 0.5 b_{xx} (\ln p)^2 + b_{xq} \ln p \ln w \\ &+ b_{xq^*} \ln p \ln \mu_q + b_{xv} \ln p \ln m + 0.5 b_{qq} (\ln w)^2 + b_{qq^*} \ln w \ln \mu_q \\ &+ b_{qv} \ln w \ln m + 0.5 b_{q^*q^*} (\ln \mu_q)^2 + b_{q^*v} \ln \mu_q \ln m + 0.5 b_{vv} \ln m \ln m\end{aligned}\right\} \quad (3.23)$$

where p is retail price output; w is price of the farm commodity; μ_q is the price "mark-down" of the farm commodity; m is labour wage; and the bs are parameters to be estimated.

The translog function is one of the flexible functional forms that permit examination of comparative statics without imposing arbitrary cross-equation restrictions. From *Hotelling's lemma*, and substituting for $\mu_q = \xi_q / \varpi_q$, the share equations of short run output supply, farm commodity input demand and labour input demand are obtained from (3.23) respectively as:

$$\frac{\partial \ln \Pi}{\partial \ln p} = s_x = b_x + b_{xx} \ln p + b_{xq} \ln w + b_{xq^*} \ln\left(\frac{\xi_q}{\varpi_q}\right) + b_{xv} \ln m \quad (3.24)$$

$$\frac{\partial \ln \Pi}{\partial \ln w} = s_q = -\left[b_q + b_{xq} \ln p + b_{qq} \ln w + b_{qq^*} \ln\left(\frac{\xi_q}{\varpi_q}\right) + b_{qv} \ln m\right] \quad (3.25)$$

and

$$\frac{\partial \ln \Pi}{\partial \ln m} = s_v = -\left[b_v + b_{xv} \ln p + b_{qv} \ln w + b_{vq^*} \ln\left(\frac{\xi_q}{\varpi_q}\right) + b_{vv} \ln m\right] \quad (3.26)$$

where $s_x = \dfrac{px}{\Pi}$ is the value of shipment of output to total profit,

$s_q = \dfrac{wq}{\Pi}$ is the cost of the farm commodity input to total profit and

$s_v = \dfrac{mv}{\Pi}$ is the cost of labour input to total profit.

All variables are defined as previously.

Assuming standard properties for the processing technology, equation (3.23) satisfies the following conditions: monotonicity and convexity in prices; symmetry; and homogeneity. Appropriate restrictions on the parameters can be imposed on (3.24) to (3.26) during estimation so that the profit function satisfies the properties of symmetry and linear homogeneity in prices.

Monotonicity and convexity are not general properties of the translog function. These properties cannot be conveniently imposed with linear restrictions on parameters in (3.24) to (3.26) (Holloway and Goddard 1988; Fulginiti and Perrin 1993; Lau 1978). Instead, the consistency of the estimated share equations with these properties must be evaluated after estimation. To satisfy the monotonicity condition, the shares fitted from the estimated parameters must be positive. The implication is that processors do not accept negative profits if all inputs are perfectly variable. To be convex in prices, the Hessian implied by the estimated price parameters must be positive semi-definite (Chambers 1988; Fulginiti and Perrin 1993). The implication is that for outputs, all own-price effects are positive and for inputs, all own-price effects are negative, as expressed by (3.07). The hypotheses of monotonicity and convexity in prices of the estimated functional forms are tested in this study. In addition, non-competitive behaviour in the domestic market for farm commodities is tested through estimation of the price "mark-down" as discussed above.

3.4.1 Responsiveness and Elasticity Measures

The dependent variables in (3.24) to (3.26) are shares that do not allow easy interpretation of the effects of prices on quantities supplied. In this case processors' responsiveness to price changes may be appropriately measured by elasticities. The elasticity measures of interest in this study are own-price elasticities of supply and demand as well as the elasticity of demand for farm commodity inputs with respect to own-price "mark-down". The elasticity formulations specified below are derived from Fulginiti and Perrin (1993). The formulation for own-price elasticity of output supply is:

$$E_{xx} = \frac{b_{xx} + s_x^2 - s_x}{s_x} \tag{3.27}$$

From (3.07) it is expected that output supply will respond positively to output price changes, i.e., that output supply will increase with an increase in output price ($E_{xx} \geq 0$). This will be an affirmation of the basic economic theory relating to supply in that supply curves are expected to be upward sloping.

Own-price elasticity of demand for farm commodity input is:

$$E_{qq} = \frac{b_{qq} + s_q^2 - s_q}{s_q} \tag{3.28}$$

From (3.07) it is also expected that own-price elasticity of demand will be negative, i.e., $E_{qq}\leq 0$ reflecting a negatively sloped demand curve for farm commodities. A similar sign is expected for own-price elasticity of demand for labour, which may be expressed as:

$$E_{vv} = \frac{b_{vv} + s_v^2 - s_v}{s_v} \tag{3.29}$$

Appropriate signs for all own-price effects are a confirmation of the convex nature of the profit function from which the functions were derived.

Following Fulginiti and Perrin (1993) the existence of substitution and/or complementarity between a farm commodity and labour in the production process is assessed using the cross-price elasticity formulation:

$$E_{ij} = \frac{b_{ij} + s_i s_j}{s_i} \qquad i,j = q,v; \quad i \neq j \tag{3.30}$$

The sign of E_{ij} depicts the technical relationship between a farm commodity input and labour in production. A positive sign implies that labour and farm commodities are substitutes while a negative sign implies that these are complements. Intuitively, we expect that the two inputs will be complementary in the food production process.

Expressions similar to (3.30) are used to calculate the elasticity of supply with respect to factor prices and the elasticity of factor demand with respect to output price. There are no prior expectations about the sign of these elasticities because economic theory does not suggest a particular sign for supply response to changes in factor prices w and m, and factor demand response to changes in output price p. From equation (3.08) supply response to changes in w, and factor demand response to changes in p are expressed respectively as:

$$\frac{\partial x^j}{\partial w} = \left\{\frac{\partial x^j(p, q^{j^*})}{\partial q^j}\right\}\left\{\frac{\partial q^j}{\partial w}\right\} \tag{3.31}$$

and

$$\frac{\partial q^j}{\partial p} = \left\{\frac{\partial q^j(w, \mu_q, x^{j^*})}{\partial x^j}\right\}\left\{\frac{\partial x^j}{\partial p}\right\} \tag{3.32}$$

where "*" indicates optimal levels. The direction of change in the expressions in the second set of brackets of (3.31) and (3.32) can be predicted using (3.07). However, economic theory does not suggest a particular direction of change in the expressions in the first set of brackets of (3.31) and (3.32). The expressions in the first set of brackets represent a change in output (input) to changes in input (output). For example, in the production process, increasing output may require an adjustment of the input mix but the extent to which individual inputs adjusts is determined by how input demand in turn responds to changes in output (Chambers 1988, p.133).

Regarding the effect of the price "mark-down," the parameter ξ_q in (3.24) to (3.26) is a local measure that measures what happens to output in a small neighbourhood of farm commodity input space. The sum of all elasticity measures of output with respect to variable inputs ξ_is, is termed the *elasticity of scale*, i.e., $\sum_i \xi_i = \xi$ (Chambers 1988). Decreasing (constant) returns to scale implies that each ξ_i is less than (less than or equal to) unity since their sum must be less than (equal to) unity. The elasticity measure of output with respect to each input is unknown. However, assuming that the profit function satisfies the aggregation property of (3.19), the production technology implied in the production process is quasi-homothetic and therefore a constant-returns technology (Chambers 1988, p. 184)[13]. With this assumption, it implies the parameter ξ equals unity. For the purposes of this study, the parameter ξ_q (elasticity of supply with respect to farm commodity input) is set at 0.5. Assuming that the parameter ξ_q is constant over the sample period, equation (3.14) implies that:

$$\mu_q = (0.5)\frac{px}{wq} = (0.5)\frac{s_x}{s_q} \qquad (3.33)$$

Any variations in the price "mark-down" μ_q will be attributed to the ratio of the optimal shares of the value of output and the value of farm commodity. From the above expression, $\partial s_q/\partial \mu_q < 0$ and $\partial s_x/\partial \mu_q > 0$. This implies that a higher price "mark-down" results in a lower share of farm commodity and a higher share of the value of output. Empirically therefore, two conditions suggest non-competitive behaviour in the farm commodity market. These are; (1) a statistically significant and positive estimate of the coefficient on μ_q in the output equation and (2) a statistically significant and negative estimate of the coefficient on μ_q in the farm commodity equation. Regarding the signs of the associated elasticity measures, the elasticity of demand for a farm commodity with respect to a price "mark-down" is expected to be positive because a high price "mark-down" depresses commodity price, resulting in increased quantity demanded for the farm commodity. This is expressed as:

$$E^{*}_{qq} = \frac{b_{qq^{*}}}{s_q} \tag{3.34}$$

Similarly, the elasticity measure of supply with respect to farm commodity price "mark-down" is expected to be positive because with more farm commodity input, more output will be produced. This is also expressed as:

$$E^{*}_{xq} = \frac{b_{xq^{*}}}{s_x} \tag{3.35}$$

3.5 Data and Estimation Procedure

Data used are annual time series for the period 1974 through 1996. The definitions and sources of the data series are summarized in Table 3.1. Four food processing industries are considered in the study; the meat and meat products (excluding poultry) industry, the cereal grain flour industry, the livestock feed industry and the vegetable oil (excluding corn oil) industry. These industries constitute part of the

[13] Quasi-homothetic production functions have expansion paths that are straight lines that do not necessarily emanate from the origin.

Canadian 1980 Standard Industrial Classification (SIC) and are identified respectively as SIC 1011, SIC 1051, SIC 1053 and SIC 1061[14].

Variables involved in the estimation process include the price index of industry output, the price of farm-commodity, the price of labour (wage), the price of energy, capital, and the generated commodity price "mark-down" variable (equation 3.33). Data on capital could not be obtained for the specified industry subdivisions. Consequently, following Bradley et al. (1993) and Holloway and Goddard (1988), operating surplus of the industry is used as a proxy for capital. Input prices and all nominal variables are deflated by the consumer price index. This implicitly imposes the homogeneity property in the supply and demand functions. With the data used, the disturbances in equations (3.24) to (3.26) are assumed to be linearly dependent because of the endogeneity of the price "mark-down" term and inaccurate measurement of capital. The system of equations is therefore estimated for each industry using the three-stage least squares (3SLS) procedure of the "SHAZAM" software program (White 1978). The consumer price index and the interest rate are used as additional predetermined variables in the estimation. Symmetry conditions (3.08) are imposed during the estimation procedure.

Preliminary results indicated the existence of multicollinearity. Therefore, all right-hand side variables used in the estimation were divided by the price of energy. Since the price of energy is not explicitly included as an explanatory variable, the equation for energy is not included in the system. For each industry, the system has three equations; output supply, farm commodity demand and labour demand. The dependent

[14] SIC 1011 refers to establishments primarily engaged in abattoir operations and/or in meat packing operations. SIC 1051 refers to establishments primarily engaged in milling flour from wheat, corn, buckwheat, rye and other cereal grains. SIC 1053 refers to establishments primarily engaged in

variables are the output and input shares. The full model for each industry comprising output supply, farm commodity demand and labour demand has 23 observations and 15 estimated parameters.

While the properties of homogeneity and symmetry are imposed, monotonicity is tested using the estimated parameters to predict shares at each data point. The monotonicity property is satisfied when predicted shares are positive at each data point. For convexity in prices, all own-price elasticities should have the expected signs, i.e., being positive for output supply and negative for input demand (Chambers 1988). Convexity in prices can also be checked using the sign definiteness of the Hessian of the sub-matrix of price coefficients (Holloway and Goddard 1988; Fulginiti and Perrin 1993). The sub-matrix of price coefficients should be positive semi-definite.

3.6 Results and Discussion

3.6.1 Model Diagnostics

Estimates of parameters, values of R-squared, Durbin-Watson (D-W) statistic, and variance of the estimates (σ-squared) for the various industry models are presented in Table 3.2. The R-squared statistic reported here is the square of the correlation coefficient between the observed and predicted dependent variable[15]. Generally, there is a reasonable level of fit for the individual equations given the values of the R-squared statistic. The values range from 0.54 for the labour demand equation in the livestock feed industry

manufacturing balanced feeds and pre-mixes or feed concentrates. SIC 1061 refers to mill establishments primarily engaged in crushing, expressing, oxidizing, dehydrating or otherwise processing oil seeds.

[15] This R-squared is not the goodness-of-fit measure which is calculated as one minus the ratio of the residual variance over the variance of the left-hand side (unexplained portion of the total variance). In 3SLS estimation, the goodness-of-fit measure of R-squared is not well defined (Berndt 1991, p. 468; Judge et al. 1988, p. 650)

model, to 0.96 for the meat supply equation in the meat and meats products industry model. The D-W statistic values are measures of first-order serial correlation in the estimated models. The D-W statistic values obtained suggest that serial correlation does not appear to be a problem in the models. The variance of the estimates, which is a measure of the difference between observed variation and predicted variation in shares, is also used to validate the models. Variance estimates are generally low ranging from 0.000 in the labour demand equation in the vegetable oil industry model, to 0.099 in the flour demand equation in the cereal-flour industry model. Low variance estimates are indications of good predictive abilities of estimated models.

3.6.2 Model Validation

In addition to model diagnostics, a more general approach to ascertaining the validity of the estimated model is to check whether the model satisfies the theoretical properties of the function from which it is derived. Homogeneity and symmetry are imposed in the estimation process but monotonicity and convexity are not. All fitted shares are positive implying that the translog profit function satisfies the property of monotonicity. In an economic sense, this implies there are no negative profits for processors when inputs are perfectly variable. The property of convexity in prices is ascertained using the eigen value test of sign definiteness. Convexity requires that all eigen values of the sub-matrix of estimated price coefficients should be non-negative and at least one should be zero for positive semi-definiteness. Eigen values obtained are: 0.341, -0.025, 0.100 for the meat products industry model; 0.426, 0.059, -0.583 for the cereal-flour industry model; -0.328, 0.018, -0.240 for the livestock feed industry model;

and 0.105, -0.024, 0.495 for the vegetable oil industry model. Eigen values from the meat industry and vegetable oil industry models appear to satisfy the condition for positive semi-definiteness. A convex profit function implies that processors can always keep output and cost constant but still increase profit with an increase in output price.

3.6.3 Test of Non-Competitive Behaviour

As illustrated in section 3.4.2, if there is non-competitive behaviour in the farm commodity market, the price "mark-down" is expected to be positive in the supply equation but negative in the farm commodity demand equation. From Table 3.2, these sign conditions are satisfied in the livestock feed industry and vegetable oil industry models. The two estimated parameters for supply and commodity demand are respectively, 5.67 and −2.431 in the feed industry model, and 3.416 and −1.036 in the vegetable oil industry model. However, the estimated parameters are not statistically significant asymptotically. Statistical significance of the parameters would have suggested the presence of non-competitive behaviour (market power) in the market for barley and canola. Nevertheless, the signs on the parameters appear to suggest that there is a limited ability or potential for the two industries to exert some market power in the market for the two commodities. In the meat products industry and cereal flour industry models, the sign conditions for the estimated parameters on the price "mark-down" are not satisfied. In both models, estimated parameters are positive in the supply and farm commodity equations. This suggests the absence of market power and absence of the potential to exert some power by these particular industries.

The finding of absence of market power in commodity markets may be attributed to a number of factors. First, the markets for feed barley and canola are unregulated and may be considered as reasonably competitive. For wheat, the Canadian Wheat Board (CWB) controls international and domestic sale of the commodity and it appears that prices are negotiated between the board and the grain milling industry. For slaughter cattle, animals are marketed through auction or private treaty, particularly in western Canada. Such market structures do not facilitate non-competitive behaviour.

Second, a substantial proportion of cereal grains and canola is exported and barley is used as a major feed ingredient in livestock production. Thus competition in the primary commodity market probably limits the ability of processors of these commodities to exert market power. Competition in the output market of the food-processing sector may also be relevant. Obligations to the General Agreement on Tariffs and Trade (GATT) have resulted in reduced tariffs on food products of the food processing industries assessed in the study. Increased cross-border trade of processor outputs also limits processors' market power.

Third, it has been speculated that firm concentration does not necessarily lead to market power, particularly when scale economies, technical change and trade factors are taken into account. For example, the US food industry has experienced increasing consolidation yet some researchers find limited or no indications of market power when cost economies, technical change, and competitiveness are considered (e.g., Azzam 1997; Azzam and Schroeter 1995; Durham and Sexton 1992; Paul 1999a, 1999b). Martin, Ball and Alexiou (1998) report that the costs of hog processing in Canada have been affected by scale and quality of plant and equipment, number of shifts, wage costs, capacity utilization and size of animals.

3.6.4 *Elasticity Measures of Price Change*

The effects of price on output supply and input demand are evaluated using elasticity measures. From an inspection of the elasticity formulation for the translog model in section 3.4.2, it is apparent that the elasticity measures will change depending on the evaluation point (i.e., as the value of shares change). It is, therefore of interest to look at the elasticity measures implied by the estimated models at points other than the mean point. The elasticity estimates evaluated at the mean of the sample period 1974-1996 are reported in Table 3.3 and the estimates evaluated at the mean of the period 1991-1996 are reported in Table 3.4. To estimate the asymptotic significance of elasticity estimates, share values are treated as constants, so that the asymptotic normal statistic can be formed (Holloway and Goddard 1988; Fulginiti and Perrin 1993).

It is expected that the sign on output supply elasticity measures will be positive. This is satisfied in all the industry models. From Table 3.3, own-price elasticity measures of output supply evaluated at the sample mean values for the meat, flour, feed and oil industries are respectively, 0.586, 0.625, 0.588, and 0.385. All estimates are statistically significant asymptotically, at the 5% level. From Table 3.4, own-price elasticity measures output supply evaluated at the 1990s mean values for the four industries are respectively, 1.223, 1.436, 1.256, and 1.116. This indicates that the supply curve for each food industry is upward sloping. The supply function in the 1990s for the various industry products of meat, flour, feed and oil all appear to be relatively price elastic. The industry is apparently able to respond to changes in consumers' demand.

Regarding factor demand elasticity estimates, *a priori* expectation of the sign on the own-price elasticity measures of input demand is that these are negative. All 8 of the estimated own-price elasticity measures of factor demand have the appropriate negative sign except in one instance, the elasticity of wheat demand, evaluated at the sample mean. The exception is an estimate of 0.193 (Table 3.3). In the meat products industry model, own-price elasticity measure of cattle demand is –0.172 and own-price elasticity for labour demand is –0.922. In the cereal flour industry model, the own-price elasticity measure of the input demand for labour –1.166. In the livestock feed industry model, own-price elasticity measure of barley input demand is –0.117 and the own-price elasticity measure of labour input demand is –1.629. Own-price elasticity measures of factor demand in the vegetable oil industry model are also negative. The corresponding own-price elasticity measures of factor demand, evaluated at the mean values for the 1990s, are all negative (Table 3.4). A negatively sloped input demand function implies that processors demand less of the factor inputs as factor price increases. This also implies that the implicit cost underlying the profit function is concave and continuous in input prices (Chambers 1988, p. 138). It appears that own-price factor demand elasticity measures tend to become larger in absolute value when evaluated at the 1990s share values than at the sample means. The translog functional form applied in the study permits the measurement of elasticity for different sample periods. Therefore it is not entirely clear whether the elasticity measures evaluated at the mean of the 1990s are more useful for policy analysis than are elasticity measures evaluated at the sample mean.

The findings of positive elasticity measures of supply and negative elasticity measures of factor demand satisfy the conditions in equation (3.07). This finding is consistent with results from the convexity property of the profit function and confirms the findings from the eigen values obtained earlier.

Regarding cross-price effects, Table 3.3, which gives elasticities evaluated at sample mean, suggests a particular relationship between farm commodities and labour used in agri-food processing. In all the farm commodity equations, the elasticity measures for demand of a farm commodity with respect to wage are negative, being -0.124 for cattle demand, -0.097 for wheat demand, -0.055 for barley demand, and –0.044 for canola demand (Table 3.3). All estimates are statistically significant, asymptotically. The implication is that labour and farm commodities are complements in food processing. However, in contrast, the elasticity estimates of demand for labour input with respect to farm commodity prices, while nonsignificant, are positive. The estimates of labour demand are 0.032 with respect to cattle price, 0.238 with respect to wheat price, 0.809 with respect to barley price and 0.644 with respect to canola price (Table 3.3). The positive signs are counter-intuitive in suggesting substitution between labour and farm commodities, but these estimates are mainly statistically insignificant, asymptotically.

From Table 3.4 (elasticity measures evaluated at 1990s mean) all estimates of cross-price effects are negative and mainly statistically significant, asymptotically. Labour and farm commodities appear as complements to each other in the respective demand equations. For example, the elasticity measures of labour demand with respect to the prices of farm commodities are –1.741 for cattle price, -1.174 for wheat price, -1.43 for barley price and –2.017 for canola price (Table 3.4). Similarly, the elasticity measures of demand for farm commodities with respect to wage are –0.186 for cattle demand, -0.171 for wheat demand, -0.107 for barley demand and –0.05 for canola demand (Table 3.4). These findings appear to be reasonable because, intuitively, we can expect labour and farm commodities to be complementary in the food production process.

The finding of complementarity between farm commodities and labour leads to expectations about the effect of commodity price "mark-down" on labour demand. With complementarity between labour and farm commodities, we would expect a positive relationship between labour demand and farm commodity price "mark-down". A higher price "mark-down" reflects a depressed commodity price and processors may consequently purchase more of the affected farm commodity. With a depressed farm commodity price and increased quantity demanded, we should expect that the demand for labour would increase as well since the two inputs are complements. From Tables 3.3 and 3.4, there is a positive relationship between labour and farm commodity price "mark-down" in all industries except for the livestock feed industry where this relationship is negative. In Table 3.3, the elasticity estimates of labour demand with respect to cattle, wheat and canola price "mark-downs" are 0.925, 0.888 and 3.321 respectively. The same elasticity measures evaluated at the mean of the 1990s' series of the data are 0.599, 0.596 and 2.745 respectively (Table 3.4).

Regarding the effect of input prices on output supply and the effect of output price on factor demand, there are no prior expectations, as pointed out in section 3.4.2. From equations (3.31) and (3.32) the effect in either case is determined by technology and by the extent to which input adjusts as output changes and vice versa. All that can be said about these elasticity measures is that from equation (3.08), the direction of the effect of a change in factor price on supply should be opposite to the direction of the effect of output price on factor demand. This condition is satisfied in all the models. In Table 3.3 for example, the elasticity measure of meat supply with respect to cattle price is 1.195 and the elasticity measure of cattle demand with respect to the price of meat products is –1.496. The elasticity measure of meat supply with respect to wage is –0.002 and the elasticity measure of demand for labour with respect to meat product price is 0.032. In each of the industry models in Tables 3.3 and 3.4, the direction of the effect of a change in factor price on supply is opposite to the direction of the effect of output price on factor demand.

In summary, the results from the estimated models generally appear to be consistent with theoretical expectations as well as economic intuition. The translog functional form applied in the study is used to approximate the profit function of food processors. The elasticity measures are the results that are probably of most interest for policy analysis but, as pointed out earlier, it is not clear which of the elasticity measures are more useful for policy analysis given the variation in absolute value from Tables 3.3 and 3.4.

3.7 Summary and Conclusions

The purpose of this component of the thesis was to examine the processing sector's demand for farm commodities and the potential presence of non-competitive behaviour (market power) in the domestic market for farm commodities. Four food industries were examined: the meat and meats products industry (excluding poultry), cereal grain flour industry, livestock feed industry and vegetable oil (excluding corn oil) industry. The profit function for each industry was specified as a translog functional form and one output supply and two factor demand models were estimated for each industry.

The results suggest that the supply curves for meat and meat products, cereal grain flour, livestock feed and vegetable oil are upward sloping. The results also indicate that the demand curves for slaughter cattle, wheat, feed barley, canola and labour are downward sloping. Own-price elasticity measures evaluated at the mean of the period 1991-1996 are larger in absolute value than estimates that are based on the sample mean which covers the period from 1974-1996. The results portray labour and farm commodities as complements in the food production process. The elasticity measures have signs that make economic sense and may be of interest for policy analysis. Regarding the issue of the existence of market power held by processors, there is no evidence of non-competitive behaviour in any of the commodity markets examined. The absence of non-competitive behaviour may be attributed to the structure of the commodity markets as well as other factors such as the increased competition from world trade that has accompanied technical change, and increased scale of food processing operations. In conclusion, it should be pointed out that the approach employed in the study may be useful in other empirical evaluations of potential imperfections and distortions in the domestic market for farm commodities.

Future research concerning the operations of the Canadian food processing industry may improve the present study in a number of ways. First, the sample period used in the study may not be long enough to evaluate any significant changes in the operations of the Canadian food processing industry. It is always preferred to have more and better data in empirical work. Second, it may be desirable to enhance the database of the processing sector, especially as this relates to the disaggregation of farm commodities and the inputs used and output produced by these industries. The database as it now exists and used here is highly aggregated. With a relatively less aggregated data, estimation of output supply and factor demand functions could be accomplished in order to examine non-competitive behaviour in both output and input markets.

Table 3.1: Processing Sector Variables: Definition and Sources of Data[1]

Variable	Definition	Source
Value of output		
SIC 1011	Value of manufactured goods	CANSIM D907976 & D662312
SIC 1051	"	CANSIM D910352 & D662389
SIC 1053	"	CANSIM D910703 & D662411
SIC 1061	"	CANSIM D912836 & D662422
Cost of farm commodity		
All industries	Cost of manufacturing materials	Statistics Canada cat # 31-203
Cost of labour		
All industries	Production workers wages	Statistics Canada cat # 31-203
Cost of energy		
SIC 1011	Cost of fuel & electricity	CANSIM D907974 & D662314
SIC 1051	"	CANSIM D910350 & D662391
SIC 1053	"	CANSIM D910701 & D662413
SIC 1061	"	CANSIM D912834 & D662424
Industry Product price		
SIC 1011	Industry Product Prices Indexes	CANSIM P1608
SIC 1051	"	CANSIM P1611
SIC 1053	"	CANSIM P1612
SIC 1061	"	CANSIM P1606
Farm commodity price		
SIC 1011 (slaughter cattle)	Calgary/Southern Alberta price.	Agriculture Canada)
SIC 1051 (wheat)	"1 CWRS" Final realized price[2]	Canadian Grain Council
SIC 1053 (barley)	"1 CW" Final realized price[3]	Canadian Grain Council
SIC 1061 (canola)	"1 Canada" price	Canadian Grain Council
Wage		
SIC 1011	Average production workers wage	Statistics Canada cat # 31-203
SIC 1051	"	"
SIC 1053	"	"
SIC 1061	"	"
Energy price		
All industries	Consumer price index for energy	CANSIM P100288

[1] The data series are presented in Appendix 3c.
[2] CWRS is an abbreviation for Canada West Red Spring
[3] CW is an abbreviation for Canada West.

Table 3.2: Estimated Coefficients for the Processing Sector Models[1].

	Meat & Meat Products Industry Model			Cereal Grain Flour Industry Model			Livestock Feed Industry Model			Vegetable Oil Industry Model		
	Meat Supply	Cattle Demand	Labour Demand	Flour Supply	Wheat Demand	Labour Demand	Feed Supply	Barley Demand	Labour Demand	Oil Supply	Canola Demand	Labour Demand
Intercept	-12.036[a]	11.55[a]	3.778[a]	-1.207	3.271	1.061	-2.149	2.964	0.567	2.196	-0.961	0.009
Wage	-0.183[a]	-0.009	-0.210[a]	-0.256	0.037	-0.270	-0.190	0.030	-0.203	-0.079	-0.010	-0.047
Capital	1.038[a]	-0.953[a]	-0.329[a]	0.316	0.402	-0.149	0.441	-0.405[b]	-0.110	0.112	-0.113	-0.013
Meat price	0.075	0.050	0.183[a]									
Cattle price	-0.050	0.068	-0.009									
Flour price				-0.117	0.348[a]	0.256						
Wheat price				-0.348[a]	0.251[a]	0.037						
Feed price							0.023	0.134	0.190			
Barley price							-0.134	0.120[b]	0.030			
Oil price										-0.228[a]	0.260[a]	0.079
Canola price										-0.260[a]	0.232[a]	-0.010
Cattle-PMD[2]	2.054[b]	0.019	0.108									
Wheat-PMD				3.505[a]	0.379	0.118						
Barley PMD							5.670[a]	-2.431	-0.230			
Canola PMD										3.416	-1.036	0.121
R-squared	0.96	0.94	0.74	0.77	0.54	0.65	0.82	0.78	0.54	0.94	0.93	0.84
σ-squared	0.012	0.009	0.001	0.099	0.048	0.001	0.068	0.040	0.001	0.018	0.013	0.000
D-W statistic	2.9	2.8	2.9	1.4	1.4	1.7	2.2	2.2	2.2	2.1	2.1	1.4

[1] 'a' indicates asymptotic significance at the 5% level and 'b' indicates asymptotic significance at the 10% level.
[2] PMD refers to price "mark-down".

Table 3.3: Estimated Elasticity Measures for the Processing Sector Evaluated at 1974-1996 Mean[1].

	Meat & Meat Products Industry Model			Cereal Grain Flour Industry Model			Livestock Feed Industry Model			Vegetable Oil Industry Model		
	Meat Supply	Cattle Demand	Labour Demand	Flour Supply	Wheat Demand	Labour Demand	Feed Supply	Barley Demand	Labour Demand	Oil Supply	Canola Demand	Labour Demand
Meat price	0.586[a]	-1.496[a]	0.032									
Cattle price	1.195[a]	-0.172[a]	-1.309[a]									
Flour price				0.625[a]	-1.362[a]	0.238[b]						
Wheat price				0.841[a]	0.193[b]	-0.767[a]						
Feed price							0.588	-1.463[a]	0.809			
Barley price							1.131[a]	-0.117[a]	-0.841[a]			
Oil price										0.385[a]	-1.334[a]	0.644
Canola price										1.130[a]	-0.120[a]	-1.583[a]
Cattle-PMD[2]	1.336[b]	0.015	0.925									
Wheat-PMD				2.068[a]	0.362	0.888						
Barley PMD							3.604[b]	-2.000	-2.883			
Canola PMD										2.227	-0.875	3.321
Wage	-0.002	-0.124[a]	-0.922	-0.019	-0.097[a]	-1.166	-0.041	-0.055[a]	-1.629	-0.015	-0.044[a]	-0.318

[1] 'a' indicates asymptotic significance at the 5% level and 'b' indicates asymptotic significance at the 10% level.
[2] PMD refers to price "mark-down".

Table 3.4: Estimated Elasticity Measures for the Processing Sector Evaluated at 1991-1996 Mean[1].

	Meat & Meat Products Industry Model			Cereal Grain Flour Industry Model			Livestock Feed Industry Model			Vegetable Oil Industry Model		
	Meat Supply	Cattle Demand	Labour Demand	Flour Supply	Wheat Demand	Labour Demand	Feed Supply	Barley Demand	Labour Demand	Oil Supply	Canola Demand	Labour Demand
Meat price	1.223[a]	-2.159[a]	-1.174[a]									
Cattle price	1.665[a]	-0.648[a]	-1.741[a]									
Flour price				1.436[a]	-2.227[a]	-1.174[a]						
Wheat price				1.222[a]	-0.178[a]	-1.174[a]						
Feed price							1.256[a]	-2.165[a]	-0.727			
Barley price							1.609[a]	-0.597[a]	-1.430			
Oil price										1.116[a]	-2.072[a]	-0.419
Canola price										1.665[a]	-0.652[a]	-2.017[a]
Cattle-PMD[2]	0.928[b]	0.011	0.599									
Wheat-PMD				1.412[a]	-0.279	0.596						
Barley PMD							2.525[b]	-1.457	-1.837			
Barley PMD										1.540	-0.637	2.745
Wage	0.096[a]	-0.186[a]	-0.348	0.095	-0.171[a]	-0.562	0.041	-0.107[a]	-0.749	0.008	-0.050[a]	-0.103

[1] 'a' indicates asymptotic significance at the 5% level and 'b' indicates asymptotic significance at the 10% level.
[2] PMD refers to price "mark-down".

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Appendix 3a: Converting Effective Marginal Cost into Elasticity Measures

The first order condition of the profit function (3.09) with respect to q^j is expressed as:

$$\frac{\partial \Pi^j}{\partial q^j} = p\frac{\partial x^j}{\partial q^j} - w + \left[q^j \frac{\partial w(q)}{\partial q}\frac{\partial q}{\partial q^j}\right] = 0$$

Multiplying the expression in parenthesis by $\frac{w\,q}{w\,q}$ and rearranging, we obtain:

$$p\frac{\partial x^j}{\partial q^j} = w + \left[w\left(\frac{\partial w}{\partial q}\frac{q}{w}\right)\left(\frac{\partial q}{\partial q^j}\frac{q^j}{q}\right)\right]$$

In elasticity form the above expression becomes:

$$p\frac{\partial x^j}{\partial q^j} = w\left(1 + \frac{\theta^j}{\varepsilon}\right)$$

where $\theta^j = \frac{\partial q}{\partial q^j}\frac{q^j}{q}$ and $\varepsilon = \frac{\partial q}{\partial w}\frac{w}{q}$

Appendix 3b: Expression for the Oligopsonistic Price "Mark-Down."

Following Hyde and Perloff (1994), the expression for the oligopsonist's price "mark-down" factor (3.13) is:

$$\mu_q = \frac{p}{w}\frac{\partial x}{\partial q}$$

Multiplying the expression on the right hand side by $\frac{x}{x}\frac{q}{q}$ and rearranging, we obtain:

$$\mu_q = \left(\frac{px}{wq}\right)\left(\frac{\partial x}{\partial q}\frac{q}{x}\right)$$

In elasticity form the above expression becomes:

$$\mu_q = \frac{\xi_q}{\varpi_q}$$

where $\xi_q = \frac{\partial x}{\partial q}\frac{q}{x}$ and $\varpi_q = \frac{wq}{px}$

Appendix 3c: Data Series Used for the Processing Sector Model

Year	Meats shipment	Flour shipment	Feed shipment	Oils shipment	Meats materials	Flour materials	Feed materials	Oils materials	Meats labour cost	Flour labour cost	Feed labour cost	Oils labour cost	Meats wage	Flour wage	Feed wage	Oils wage
1974	3578951	478612	1221640	295628	2919992	350613	1011966	266693	231702	32331	46169	5232	4.58	4.76	3.9	4.32
1975	3828825	561853	1256696	288978	3097744	399614	1020942	250739	278193	37023	55729	5650	5.41	5.38	4.37	5.24
1976	3989997	602100	1292509	312405	3175541	424613	1037624	274189	318457	43166	59014	7903	6.04	6.16	5.08	5.95
1977	4258368	617450	1366746	437857	3400472	427331	1089169	393368	344641	47801	62867	10471	6.58	6.54	5.56	6.49
1978	5515356	657058	1532794	493256	4573548	453118	1213912	428861	367791	50742	72900	12433	6.94	7.1	6.04	6.79
1979	6587418	798591	1895822	595540	5492498	573189	1534616	540809	399014	56958	80962	13815	7.56	7.58	6.58	7.76
1980	6829435	923117	2280731	738829	5719259	669106	1844283	640896	458464	60771	92528	17713	8.29	8.45	7.23	8.97
1981	7574855	1216549	2524205	829029	6301529	803693	2058444	721911	518858	76104	101098	21856	9.32	9.55	8.12	10.14
1982	7919954	1206749	2417329	722455	6630576	739604	1910956	651789	553513	84475	105966	23390	10.35	10.66	8.78	11.57
1983	7853666	1182264	2505183	834176	6414043	749198	1972869	776491	572554	91382	110913	23418	11.38	12.09	9.4	12.22
1984	8277238	1223243	2660167	964225	6759604	810582	2107257	858737	559652	98810	116408	23852	11.46	12.73	9.89	13.54
1985	8248452	1305392	2623730	987059	6803941	840987	2002631	866981	569461	108164	124101	23824	11.6	12.97	10.25	14.4
1986	8530573	1395355	2536736	732119	6925099	899359	1908457	636456	591572	114287	126999	21589	11.95	14.14	10.66	14.8
1987	9128650	1457673	2490325	771883	7697472	1213879	2186501	707225	638901	120616	132759	23461	12.34	14.62	11.08	14.97
1988	8743910	1488682	2913482	967986	6827500	926800	2250200	792100	662947	122534	153287	23592	12.73	15.11	11.51	15.14
1989	8722771	1526845	3091085	854412	6962200	902900	2403500	717000	701173	126274	164607	23094	13.04	15.77	11.9	15.07
1990	8962603	1427486	2773491	803906	7087100	803800	2044600	658400	702200	123733	158700	21379	13.15	16.77	12.79	16.27
1991	8486684	1314990	2612861	827967	6530900	692400	1924400	682200	694013	117516	155868	19012	13.74	17.64	13.13	16.99
1992	8521200	1441899	2717800	974311	6387800	732800	1982700	759000	739361	124348	164753	21361	13.68	17.58	13.6	16.26
1993	9215512	1503196	2880791	1065671	7258400	806200	2120000	883600	740300	134463	173499	24056	13.6	18.62	13.9	18.21
1994	9530425	1705581	3170025	1412581	7469700	968300	2338200	1071700	770156	130867	178803	26911	14.08	18.27	13.96	17.79
1995	9637489	1809862	3456721	1781341	7435000	1021500	2621500	1414200	805416	129390	179802	31533	14.45	18.28	14.35	18.28
1996	10202373	1987474	4022453	1909663	7805400	1166000	3055300	1602100	815332	129855	186036	29398	14.14	17.84	14.1	18.84

continued on next page

Appendix 3d: Data Series Used for the Processing Sector Model

Year	Meats energy cost	Flour energy cost	Feed energy cost	Oils energy cost	Meats price	Flour price	Feed price	Oils price	Wheat price	Barley price	Canola price	Cattle price	CPI	Energy CPI	Interest Rate
1974	20006	3389	11679	2508	51.3	41.4	62.2	107.8	164.39	107.05	318.95	846.68	31.1	22.8	10.51
1975	24897	4212	11981	3245	55.3	41.7	61.4	95.8	146.27	104.06	226.8	707.52	34.5	25.9	7.94
1976	30393	5480	14586	4654	54.4	41.8	62.9	93.6	117.15	91.5	282.13	675.22	37.1	29.9	9.17
1977	33772	6610	17246	6266	55	42.6	66.3	108.9	120.3	88.39	295.94	727.65	40	33.5	7.48
1978	37389	7646	20037	7590	70	45.1	68	104	160.53	91.08	304.77	1089.6	43.6	36.6	8.83
1979	43873	8626	23502	8746	81.5	61.9	79.3	114	196.43	107.47	309.04	1517.92	47.6	40.2	12.07
1980	54342	9708	28587	10835	81.6	71.3	87.1	110.1	222.12	146.55	329.35	1402.43	52.4	46.6	13.15
1981	65387	11962	35105	13953	85.8	83.9	95.1	111.6	199.62	131.07	325.19	1330.31	58.9	60.6	18.33
1982	76931	14179	47063	17199	91.2	81.4	91	104.4	192.34	110	306.99	1260.4	65.3	72.6	14.15
1983	81063	15164	51675	19188	89.2	82.1	96.2	113.2	193.98	138.02	455.44	1305.09	69.1	78.3	9.45
1984	80478	16181	54672	17393	93.7	87.4	99.9	134.4	186.37	131.3	386.04	1365.49	72.1	82.6	11.19
1985	82878	17259	55980	19386	93	92	93.9	118.2	160	110	301.4	1261.5	75	87.2	9.56
1986	80831	18879	51608	16984	97.4	100	91.9	102.4	130	80	239.7	1319.03	78.1	81	9.16
1987	82805	19078	51175	17659	101.5	100.7	90.4	93	134.02	74.08	303.35	1339.82	81.5	83.1	8.38
1988	83778	19175	57089	16977	99.8	103.6	103.4	115.2	197.14	124.23	337.4	1325.44	84.8	83.6	9.67
1989	86905	19967	55258	16173	98.9	105.7	107.3	110.2	172.11	124.38	303.72	1307.74	89	86.5	12.21
1990	90233	19515	52860	16356	103.2	99.3	103.5	103.1	135	90	287.72	1749.78	93.3	95.1	13.03
1991	92346	20615	55999	16324	100.6	92.8	99.5	98.5	134.14	107.59	274.85	1677.88	98.5	99.7	8.91
1992	97600	22678	52700	17053	100	104.5	100	100	156.82	102.46	321.61	1648.45	100	100	6.74
1993	103502	25743	56630	19323	110.2	111.3	102.6	111.9	164.01	99.94	391.38	1857.08	101.8	101.2	4.97
1994	113520	30025	63739	24672	112.4	120.9	107	128.8	195.59	101.94	412.18	1901.99	102	101.8	5.66
1995	108548	27201	64619	27563	114.1	130.8	112.2	127.8	254.16	205.49	479.8	1833.85	104.2	103.2	7.22
1996	109166	27919	63109	23871	121.7	142.7	129.7	136.1	208.2	150.97	441.1	1734.96	105.8	106.2	4.35

4. CANADIAN RETAIL DEMAND FOR FOOD

4.1 Introduction

Value-added policies by the various levels of government in Canada are directed toward stimulating or changing the demand for farm commodities. Long-term growth in value-adding activities depends primarily on growth in effective demand for value-added products. Therefore, in the long-term, consumer response to changes in food prices and income is paramount if the objectives of value-added policy are to be achieved.

Studies of food demand in Canada as in some other nations have revealed that the relative importance of some major food groups is changing. The relative importance of meats, especially red meats, has declined and poultry and other food groups, especially complex carbohydrates, fresh vegetables and fruits, are becoming more important (Agriculture and Agri-Food Canada 1990). For red meats, there seems to be a consensus among researchers that there has been a change in demand (Reynolds and Goddard 1991; Xu and Veeman 1996:) although the precise cause of this continues to be debated. Some studies suggest that the trend in food consumption over the past two decades may be due to the effects of changing relative prices, convenience and rising popularity of fast-food restaurants (Alston and Chalfant 1991; Brester et al. 1997; Eales 1996). Other studies have attributed the changes in food consumption patterns to rising incomes, health consciousness, demographic trends, and rising popularity of ethnic meals (Agriculture and Agri-Food Canada 1994; Beggs et al. 1993; Quagrainie 1995; Ward and Moon 1996). The nature of changes in the demand for food and their underlying causes are of interest to the food industry and policy makers.

Much research on food demand appeals to the framework of short run constrained utility maximization, where consumers are assumed to fully adjust to price and income changes instantaneously. However, Anderson and Blundell (1983) suggest that consumers are unlikely to have adjusted to equilibrium in every time period. Habit persistence, adjustment costs, incorrect expectations and misinterpreted real price changes are among many possible reasons for such short run behaviour. Studies have reported improvement in the performance of demand models when habit persistence is incorporated (e.g., Chen and Veeman 1991; McGuirk et al. 1995). It has been suggested that appropriate modelling of the dynamic adjustment of consumers' expenditure is important (Deaton and Muellbauer 1980b, p. 373-377; Pollack and Wales 1981).

This component of the thesis contributes to the literature on consumer demand in two major ways. First, unlike many previous studies, this study investigates both short run and long run demand patterns for food in Canada. Consumer response is partitioned into both short run and long run for a better prediction of consumer response to changes in economic factors. Second, this study constructs and estimates a complete system of consumer demands for food, placing emphasis on meats. Many studies have estimated partial demand systems focussing on subsets of food groups that are viewed as being separable. With such demand specifications, the potential growth in effective demand for food may be better predicted. This can be useful for policy purposes.

This portion of the thesis is organized as follows; the following section outlines the theoretical framework for the models that are used. In this section an outline of the Almost Ideal Demand System (AIDS) model of Deaton and Muelbauer (1980a) is given. Following this the data and estimation procedure used in the study are outlined. Results are then presented and compared with results from some previous studies. Finally, some conclusions are drawn concerning the use of the static demand models versus dynamic modelling, and the implications of the results for policy.

4.2 Theoretical Framework

The fundamental theory of consumer demand and properties of consumer demand functions and their applications are outlined in standard microeconomics textbooks. Examples are Varian (1992) and Deaton and Muellbauer (1980b). In this section however, some theoretical assumptions are highlighted and the estimation models are presented.

4.2.1 Separability Assumption

The theoretical framework that is employed makes use of the separability assumption in applied demand analysis. The separability assumption may be applied in two ways. First, it allows individuals to determine optimal expenditures on food based on a two-stage budgeting procedure. In this study, individuals are assumed first to allocate their disposable income to expenditure on food consumed at home, food consumed away from home and non-food goods. Consumers then allocate total consumption expenditure on food consumed at home between expenditure on major food groups, i.e., meats, dairy foods, cereal and bakery products, and other foods (Figure 4.1). Thus, the separabilty assumption permits a specification and estimation of a complete demand model, which accounts for the first stage of income allocation.

Second, where aggregation across commodities or two-stage budgeting is not possible, the separability assumption also permits the specification and estimation of a subgroup of goods in isolation from other goods, e.g., empirical analysis of the demand for meats. Most of the studies of the demand for food have been conducted under this form of separability assumption. The problem with this approach is that the first stage income allocation is not specified. Thus, the resulting elasticity estimates from the demand functions are not appropriate for policy purposes.

In this study, the full demand model involving the specifications of the first and second stages of income allocation is estimated. The empirical specifications apply the general dynamic model developed by Anderson and Blundell (1983). This permits the investigation of the short run and long run demand patterns of food in Canada. This general dynamic model conforms to orthodox demand theory and allows partitioning of the dynamic model into long run and short run components. The dynamic model is applied to the linear version of the almost ideal demand system (LAIDS).

4.2.2 *The Almost Ideal Demand System (AIDS)*

The almost ideal demand system belongs to the family of flexible demand systems and is derived from a specific class of preferences, known as the price-independent generalized logarithmic (PIGLOG) class. The cost function from this class of preferences is written as:

$$\ln c(p,u) = \alpha_0 + \sum_i \alpha_i \ln p_i + 0.5\sum_i \sum_j \alpha_{ij} \ln p_i \ln p_j + u\beta_0 \prod_i p_i^{\beta_i} \qquad (4.01)$$

where $c(p,u)$ is the minimum expenditure necessary to attain a given level of consumer utility u, at given prices p. The cost function of (4.01) is invertible, by which a closed form expression can be derived for the utility function, u. The orthodox almost ideal demand system specification, obtained from (4.01), is of the form:

$$c_i = \alpha_i + \sum_j \alpha_{ij} \ln p_j + \beta_i \ln(\frac{M}{P}) \tag{4.02}$$

where c_i is the share of good i in consumer expenditure ($p_i x_i / M$), and x_i is the retail quantity of commodity i; p_j is the price of good j; M is the total expenditure on food; and P is a price index defined as:

$$\ln P = \alpha_0 + \sum_i \alpha_i \ln p_i + 0.5 \sum_i \sum_j \alpha_{ij} \ln p_i \ln p_j \tag{4.03}$$

The almost ideal demand system specification of (4.02) is non-linear because of the price index P. A linear version of the almost ideal demand system specification (LAIDS) involves the use of Stone's price index, [$\ln P^* = \Sigma_j c_j \log(p_j)$], instead of the price index of (4.03). The LAIDS is applied in this study because it is known to approximate the non-linear AIDS model quite well (Asche and Wessels 1997; Deaton and Muellbauer 1980a; Wellman 1992). The theoretical properties of (4.02) require the following restrictions on the parameters:

$$\sum_i \alpha_i = 1, \qquad \sum_j \alpha_{ij} = 0, \qquad \text{and} \qquad \sum_i \beta_i = 0 \tag{4.04}$$

Substitution of (4.03) and (4.04) into (4.02) and rearranging gives:

$$\begin{aligned} c_i = {} & (\alpha_i - \beta_i \alpha_n) + \sum_{j=1}^{n} (\alpha_{ij} - \beta_i \alpha_j) \ln p_j + \beta_i \ln M - \beta_i 0.5 \sum_{j=1}^{n-1} \alpha_{jj} (\ln p_j^2 - \ln p_n^2) \\ & - \beta_i 0.5 \sum_{j=1}^{n-1} \sum_{k=j+1}^{n} (\alpha_{jk} - \alpha_{kj})(\ln p_j \ln p_k - \ln p_n^2) \end{aligned} \tag{4.05}$$

In a more compact form expressed as a vector, (4.05) becomes:

$$c = \Pi(\Theta)X \tag{4.06}$$

where Π is the function; X is a matrix containing an intercept, log price, the income term and the transformed log price terms: and Θ is a vector of parameters. The vector of parameters can be derived from non-linear restrictions on the function Π. The formulation in (4.05) and/or (4.06) corresponds to long run preferences and there are nested restrictions that can be tested on the long run parameters. The general long run formulations, nested restrictions, and their implications for demand elasticities are described in Anderson and Blundell (1982, 1983). The formulations in Anderson and Blundell (1982, 1983) as applied to the linear version of the almost ideal demand system model are presented below.

4.2.3 *The Flexible Dynamic LAIDS Model*

Given a time series of T observations on budget shares, price and per capita income, a general first-order dynamic model of (4.06) may be written as[16]:

$$\Delta c_t = A^* \Delta X_t - B^* (c_{t-1} - \Pi(\Theta) X_{t-1}) + \varepsilon_t \tag{4.07}$$

where Δ represents the first difference operator; A^* and B^* are appropriately dimensioned matrices of coefficients; and ε_t is a vector of disturbances assumed to be singular, independent and identically distributed over time. Anderson and Blundell (1982, 1983) show that an estimable form of (4.07) may be written as:

$$\Delta c_t = A \Delta \tilde{X}_t - B(c_{t-1} - \Pi(\Theta) X_{t-1}) + \varepsilon_t \tag{4.08}$$

[16] Applied economists commonly use the first difference of the LAIDS model in demand analyses. This first difference was developed by Deaton and Muellbauer (1980a) and has subsequently been used in numerous studies (e.g., Alston and Chalfant 1991; Moschini and Moro 1993; Reynolds and Goddard 1991).

where A and B are n x (n-1) dimensional matrices of coefficients and $\tilde{X}_t$ is X_t with the constant term excluded. Parametric restrictions on A and B and identification issues are outlined in Anderson and Blundell (1982, 1983).

The formulation in (4.08) is a general first-order dynamic model applicable to a demand system that distinguishes short run and long run responses to changes in market conditions. Following Anderson and Blundell (1983), Burton and Young (1992, 1996), and Asche et. al (1997) a dynamic linear version of the almost ideal demand system model of the form (4.08) may be expressed as:

$$\begin{aligned} c_{it} - c_{it-1} &= \lambda(\alpha_i + \sum_j \alpha_{ij} \ln p_{jt-1} + \alpha_{i0} \ln M^*_{t-1} - c_{it-1}) \\ &+ \sum_j \beta_{ij} \ln(\frac{p_{jt}}{p_{jt-1}}) + \beta_{i0} \ln(\frac{M^*_t}{M^*_{t-1}}) \qquad i, j = 1, \ldots, n \end{aligned} \tag{4.09}$$

where M^* is total expenditure deflated by Stone's price index; λ is a coefficient that measures the speed of adjustment: the parameters αs are long run responses; and the parameters βs are short run responses. The model can be estimated to impose theoretical properties of demand functions, i.e., adding-up, homogeneity and symmetry, that is:

Adding up: $$\sum_i \alpha_i = 1; \quad \sum_i \alpha_{ij} = 0; \quad \sum_i \alpha_{i0} = 0; \quad \sum_i \beta_{i0} = 0 \tag{4.10}$$

Homogeneity: $$\sum_j \alpha_{ij} = 0; \quad \sum_j \beta_{ij} = 0 \tag{4.11}$$

Symmetry: $$\alpha_{ij} = \alpha_{ji}; \quad \beta_{ij} = \beta_{ji} \tag{4.12}$$

In equation (4.09) current changes in budget shares depend on current changes in prices and expenditures as well as on the extent of consumer disequilibrium in the previous period.

4.3 Empirical Models

As mentioned earlier, a two-stage budgeting procedure is assumed in the analysis. Individuals are assumed first to allocate their disposable income to expenditure on food consumed away from home, food consumed at home, and non-food goods. Total consumption expenditure on food consumed at home is then allocated to expenditure on beef, pork, chicken, dairy foods, cereal and bakery products, and other food groups (see figure 4.1). The separability structure in Figure 4.1 postulates three major groups of goods namely food consumed away from home, food consumed at home and non-food goods. Within the food consumed at home group, beef, pork, chicken, dairy products, bakery products and other foods are identified[17].

Specifically, the first stage income allocation is specified for food consumed away from home (FA), food consumed at home (FH), and non-food goods (NF) as:

$$\begin{aligned} c_{it} - c_{it-1} &= \lambda\Big(a_i + \sum_j a_{ij} \ln p_{jt-1} + a_{i0} \ln M^*_{t-1} - c_{it-1}\Big) \\ &\quad + \sum_j \tilde{a}_{ij} \ln\Big(\frac{p_{jt}}{p_{jt-1}}\Big) + \tilde{a}_{i0} \ln\Big(\frac{M^*_t}{M^*_{t-1}}\Big) \qquad i; j = \text{FA}, \text{FH}, \text{NF} \end{aligned} \tag{4.13}$$

where c_{it} is the expenditure share of commodity group i in period t; p_j is the price index of commodity group j; M^* is total expenditure deflated by Stone's price index [ln $P^* = \Sigma_j c_j$ $\log(p_j)$],; λ is an adjustment coefficient; the parameters as are long run responses; and the parameters $\tilde{a}$s are short run responses.

The second stage income allocation is specified for beef (B), pork (P), chicken (C), dairy products (D), bakery products (K) and other foods (O) as:

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[17] For policy purposes, it may have been appropriate to specify and estimate a more disaggregated form of commodity categories, e.g., housing, clothing, transportation, beef, pork, chicken, milk, cheese, etc. in the second stage. Estimation of such complete disaggregated specifications would involve many equations and

$$
\begin{aligned}
c_{kt} - c_{kt-1} &= \lambda(u_k + \sum_l u_{kl} \ln p_{kt-1} + u_{k0} \ln F^{*}_{k-1} - c_{kt-1}) \\
&+ \sum_l \hat{u}_{kl} \ln(\frac{p_{kt}}{p_{kt-1}}) + \hat{u}_{k0} \ln(\frac{HF^{*}_{t}}{HF^{*}_{t-1}}) \qquad k,l = \mathrm{B,P,C,D,K,O}
\end{aligned}
\tag{4.14}
$$

where c_{kt} is the expenditure share of good k in period t; p_k is the price (or price index) of good k; HF^{*} is expenditure on food consumed at home deflated by Stone's price index [ln $P = \Sigma_k\ c_k\ \log(p_k)$]; λ is an adjustment coefficient; the parameters us are long run responses; and the parameters $\hat{u}$s are short run responses. The adjustment coefficient λ, is the same in each equation and in a steady state, (4.13) and (4.14) reduce to functions similar to (4.02). Thus, one of the hypotheses to be tested in this study is whether λ equals one. Non-rejection of the null hypothesis implies that consumers adjust to equilibrium instantaneously from a disequilibrium due to price and income changes.

The flexible dynamic linear version of the almost ideal demand system specified in equations (4.13) and (4.14) are estimated jointly and simultaneously using the non-linear version of the iterative seemingly unrelated system regression procedure of SHAZAM (version 7.0). To avoid singularity of the variance-covariance matrix, the equation for "other foods" is deleted in the estimation process. The properties of homogeneity and symmetry are maintained for both stages. A total of 58 parameters are estimated with 7 equations (2 equations for the first stage and 5 equations for the second stage). The estimated coefficients include an adjustment coefficient, 12 parameters for the first stage and 57 parameters for the second stage.

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a problem with degrees of freedom. For practical necessity and interest in the livestock sector, this study considers only the meats category in the disaggregated form.

4.4 Data Requirements

Annual data from 1961 to 1997 are used for the study. The definition of variables and the sources of data are reported in Table 4.1. Most of the data used are obtained from the Statistics Canada database, CANSIM. Annual expenditures from the system of national accounts of Statistics Canada provided data on consumer expenditure in both current and constant dollars (1992 prices). Because the constant price expenditures are essentially fixed-weights or Laspeyers quantity indices, the implicit price for a category is obtained by dividing current by constant price expenditures (Moschini and Moro 1993). Statistics Canada is also the source of quarterly expenditures on broad aggregates of consumer goods and services and consumer price indices (CPI) for the aggregates as well as for specific food categories. Expenditure data on the non-food group is calculated as the total personal expenditure on goods and services minus total personal expenditure on food consumed at home and food consumed in restaurants and hotels. The calculation is done in both current dollars and constant dollars. The ratio of the two generated series provides an implicit price index for the non-food group.

Although the data obtained from Statistics Canada provided much of the information required for the structure assumed in Figure 4.1, no expenditure data are available on specific food categories such as beef, pork and chicken. To separate expenditure on meat products provided by Statistics Canada into expenditures on beef, pork and chicken, the procedure proposed by Moschini and Moro (1993) and Moschini and Vissa (1993) is followed. This procedure is explained below.

4.4.1 Disaggregating Meat Expenditures

The procedure proposed and adopted by Moschini and Moro (1993) and Moschini and Vissa (1993) uses data from the Food Expenditure survey (Statistics Canada, *Family Food Expenditure in Canada*). This survey provides periodic detailed average weekly data on quantities purchased and expenditures on food by Canadian families. The nominal price for a food item is calculated as the ratio of expenditures to the quantities consumed per household. Data are available for specific commodities for the years 1969, 1974, 1976, 1978, 1982, 1984, 1986, 1990 and 1992. For beef, pork and chicken, the average prices calculated by Veeman and Peng (1997, p. 11) are used. Regressing annual nominal prices through the origin on the corresponding annual consumer price index for the years produced the following results:

$$P_{beef} = \underset{(0.0018)}{0.068}\, CPI_{beef} \qquad R^2 = 0.93$$

$$P_{pork} = \underset{(0.0005)}{0.054}\, CPI_{pork} \qquad R^2 = 0.98$$

$$P_{chicken} = \underset{(0.0013)}{0.041}\, CPI_{chicken} \qquad R^2 = 0.91$$

Standard errors are reported in brackets. Multiplying these estimated coefficients by the whole series of consumer price indices for the period of interest yields estimated series for retail prices of beef, pork and chicken.

The period defined for this study is from 1961 to 1997, but consumer price index data for beef and pork obtained from Statistics Canada begins at 1971 and 1978 respectively. Price indices for earlier years were unavailable from Statistics Canada. However, Chen (1991) reports retail price series for beef and pork developed from an earlier consumer price series (1960 to 1987). The procedure outlined above was followed to develop consumer price indices for beef and pork for the earlier years that data are not available. Regressing the available annual consumer price index through the origin on the corresponding annual retail prices from Chen (1991) produced the following results:

$$CPI_{beef} = \underset{(0.002)}{12.772}\,P_{beef} \qquad R^2 = 1.00$$

$$CPI_{pork} = \underset{(0.066)}{13.456}\,P_{pork} \qquad R^2 = 1.00$$

Standard errors are reported in brackets. Multiplying these estimated coefficients by the complete retail price series reported by Chen (1991) yields estimates of consumer price indices for beef (1961 to 1970) and pork (1961 to 1977). These consumer price indices are then multiplied by the parameters from the earlier regression to obtain retail prices for beef (1961 to 1970) and pork (1961 to 1977).

The procedure employed above is not without problems. There is a potential for bias due to errors in measurement of the generated variables (Kennedy 1992). Nevertheless, in view of the low standard errors and high R-squared values obtained, the potential bias may not be a major issue.

Multiplying the generated retail prices for beef, pork and chicken by the corresponding quantity disappearances (retail weight), gives estimated expenditures for each of the three meat types. The share of each meat category is then calculated from the estimated expenditures as a ratio of estimated expenditure for each meat type to total meat expenditure. The calculated shares (percentages) are used to allocate the total expenditure on meats reported by Statistics Canada to expenditures on beef, pork and chicken.

4.5 Results and Discussion

The dependent variables are first differences of shares, but right-hand side variables are varied. Right-hand side variables applicable to the long run are one-year lags of prices, expenditures and shares while variables applicable to the short run are first differences of prices and expenditures.

The estimated coefficients for the separable structure and their t-ratios are presented in Table 4.2. The estimate on the adjustment coefficient (λ) is 0.435 and is statistically significant. The null hypothesis of a steady state, i.e., that consumers fully adjust to price and income changes instantaneously (λ=1), is tested. The null hypothesis is rejected using a Wald test at the 5% level of significance. The implication is that consumers do not fully adjust to price and income changes instantaneously, as is assumed in static models. Static demand models assume a steady state where consumers adjust to equilibrium in every time period. This finding suggests that specifying and estimating demand models in a static framework may not be appropriate. As Anderson and Blundell (1983) point out, there are adjustment costs, expectations and varied interpretations of real price changes so that consumers are unlikely to adjust to equilibrium in every time period. The nature of the adjustment process is, however, an empirical question.

The sign on the estimated coefficients for expenditures from the model allows goods/commodities to be classified as "luxuries" or "necessities." Luxuries are commodities whose expenditure shares increase with income ($a_{i0}>0$; $\hat{a}_{i0}>0$; $u_{k0}>0$; and $\hat{u}_{k0}>0$) and necessities are commodities for which expenditure shares decrease with income ($a_{i0}<0$; $\hat{a}_{i0}<0$; $u_{k0}<0$; and $\hat{u}_{k0}<0$). In the short run, food consumed away from home and the non-food group appear to be luxuries ($\hat{a}_{A0}$ and $\hat{a}_{N0}$ respectively in Table 4.2). The respective estimated parameters are 0.019 and 0.063; both estimates are statistically significant. Dairy products appear to be necessities in the short run ($\hat{u}_{D0}$ in Table 4.2). In the long run, bakery and beef products appear to be luxuries ($u_{B0}>0$ and $u_{K0}>0$ in Table 4.2).

4.5.1 Elasticity Estimates for First-Stage Income Allocation

Short run and long run elasticity formulations from (4.13) and (4.14) are presented in Appendix 4a. Uncompensated and compensated price elasticity measures as well as expenditure elasticity measures are calculated at the means of the sample period (1961-1997) and the 1990s (1991-1997) for each category. This is done for comparison purposes. Uncompensated and compensated elasticity estimates for the first-stage income allocation are reported in Tables 4.4 and 4.5 respectively. All of the discussion and references to elasticity estimates given below apply to the estimated uncompensated elasticity measures at the means.

All own-price elasticity measures have the expected signs in the long run and the short run; each is relatively price-inelastic and all are significant at the 5% level. A test of the difference between the short run and the long run own-price estimates indicate that there is no statistically significant (5% level) difference between the two estimates. From Table 4.3, the measures of short run own-price elasticity of demand at sample mean for food consumed away from home and the non-food group are -0.692 and –0.976 respectively. It appears that demand for non-food is relatively price elastic compared to food consumed away from home in both the short run and long run. This suggests that as prices increase, there is a tendency for consumers to be more responsive to changes in the price of non-food items than to changes in prices of food at restaurants and hotels. The short run own-price estimates are comparable to those reported by Moschini and Moro on data from 1962 to 1988 (see Table 4.5). The studies by Moschini and Moro (1993) and Veeman and Peng (1997) reported in Table 4.5 have been conducted in a short run framework.

The negative signs on the cross-price elasticity estimates reported in Table 4.3 indicate that food consumed away from home and non-food items are gross complements. The expenditure elasticity measures for food consumed away from home and non-food are all positive and statistically significant at the 5% level. In the short run and in the long run, results suggest that both categories of goods are expenditure elastic (greater than unity), i.e., as income increases, demand for these goods increase far more than the increase in income.

Table 4.4 reports the compensated price elasticity measures for the first-stage income allocation. All own-price compensated elasticity measures have the appropriate negative sign and are statistically significant at the 5% level. Thus, an increase in price with utility held constant must cause demand for a good to fall. This finding confirms the "law of demand," that compensated demand functions slope downwards. From appendix (4a), the Slutsky relationship may be written as $[E_{ii}^{uncomp} = E_{ii}^{comp} - \eta_i c_i]$ so that the uncompensated own-price elasticity is decomposed into own-price substitution effect (E_{ii}^{uncomp}) and income effect ($-\eta_i c_i$) of a change in own-price. From this formulation, it can be seen that the own-price compensated response is reinforced by the income effect thus, all the goods are deemed normal goods. Regarding cross-price effects, the signs on the compensated cross-price elasticity estimates suggest that food consumed away from home and non-food are substitutes.

In summary, the results obtained in this component of the study indicate that food consumed away from home and non-food goods are normal goods and that the demand curves for these goods are negatively sloped. All estimated own-price elasticity measures are negative and statistically significant at the 5% level. Food consumed away from home and non-food goods appear to be expenditure elastic. Regarding cross-price effects, uncompensated elasticity estimates suggest that food consumed away from home and non-food items are complements but the compensated elasticity estimates suggest they are substitutes. Moschini and Moro (1993) report the same findings.

4.5.2 *Elasticity Estimates for Second-Stage Income Allocation*

Uncompensated price elasticity estimates and expenditure elasticity estimates for the second-stage income allocation are presented in Table 4.6. The categories are beef, pork, chicken, dairy products and bakery products. Compensated price elasticity measures are presented in Table 4.7. For comparison purposes, the elasticity estimates for each category of food commodity are calculated at the means of the sample (1961-1997) and of the 1990s (1991-1997). However, in the discussion on elasticity estimates that follows, the focus is on elasticity measures evaluated at the sample means.

All own-price elasticity measures have the expected negative sign and all expenditure elasticity estimates have the expected positive sign. Measures of uncompensated own-price elasticity in the long run appear to be larger in size compared to measures in the short run (Table 4.6). A test of the difference between the short run and the long run own-price estimates indicate that there is no statistically significant (5% level) difference between the two estimates except the own-price estimates of beef. In the short run, measures of own-price elasticity of demand for beef, pork, chicken, dairy products and bakery products are –0.558, -0.430, -0.309, -0.535 and –0.546 respectively. In the long run, the corresponding elasticity measures are -1.255, -0.453, -0.214, -0.888 and –0.654 (Table 4.6). The elastic nature of beef demand in the long run suggests an increasing possibility of consumers substituting other meats for beef in the long run. The demand for chicken and pork does not show any appreciable change in elasticity measures between the short run and the long run. The demand for chicken is the least price-responsive among the food categories. This may be associated with the feature that Canadian consumers are increasingly substituting the consumption of chicken for other meats. A variety of reasons has been given for this feature including the convenience of cooking chicken and that it contains less saturated fat (Eales 1996; Reynolds and Goddard 1991; Quagrainie 1995; and Xu and Veeman 1996).

Substitute relationships are found between beef and pork, beef and chicken, and pork and chicken. The relationships between beef and chicken, and pork and chicken are strong; all elasticity estimates in the short run and long run are statistically significant at the 5% level (Table 4.6). Results suggest complementary relationships between beef and bakery products, pork and dairy products, and chicken and dairy products although the estimates are not statistically significant.

All the expenditure elasticity measures are statistically significant at the 5% level. In the short run, the demand for chicken, dairy products and bakery products are expenditure inelastic but demand for the three food products are expenditure elastic in the long run. For beef, there is not much change in the responsiveness of demand to income but demand for pork is expenditure elastic in the short run and expenditure inelastic in the long run. The implication is that with an increase in expenditure allocation for food consumed at home, consumers will tend to spend more on chicken, dairy products and bakery products but not on beef and pork in the long run.

Comparison of results from this study with those from some other studies can be made from Table 4.5. Since previous studies were conducted in the short run framework, short run elasticity estimates are compared. The estimates of short run own-price elasticities from this study tend to be somewhat lower for chicken and pork. While this study reports own-price elasticity estimates for the demand for pork and chicken of –0.43 and –0.31 respectively, Moschini and Moro report –0.62 and –0.72 for pork and chicken respectively. Veeman and Peng report –0.75 and –0.69 for pork and chicken respectively. For beef, the own-price elasticity measure from this study compares well with that reported by Moschini and Moro, and for dairy, the own-price elasticity measure from this study compares well with that reported by Veeman and Peng. Expenditure elasticity estimates for the food groups also compare well with the two cited studies except for pork and dairy. For these two items, expenditure elasticity estimates from this study are somewhat higher than in the two noted previous studies.

Table 4.7 reports compensated price elasticity estimates for the second-stage income allocation. All the own-price elasticity estimates for the five categories of food are price inelastic. Estimated own-price compensated elasticities are statistically significant at the 5% level except for chicken. The demand for chicken exhibits the least own-price elasticity, which is consistent with the estimated uncompensated elasticities. In the long run, the demand for beef is own-price elastic with an estimated elasticity measure of −1.161. As alluded to earlier, the elastic nature of beef in the long run reflects the increased possibility of substitution in demand with other meat products. This possibility is enhanced by the apparent cross price relationships between beef and other meats. The elasticity measures reported in Table 4.7, suggest strong substitution relationships between beef and pork, and between beef and chicken. The apparent consumer attitudes towards beef, suggested by the demand parameters noted above should be of concern to the beef industry. Many other surveys and studies suggest that consumers may have health concerns about beef and are willing to compromise on taste in exchange for products perceived as healthy (Eales 1991; Quagrainie 1995). Thus, the beef industry must continue to improve the safety and perceptions of its products and pursue product development and consumer education initiatives concerning health and safety issues. The apparent elasticity of beef demand in the long run also suggests the need for the beef industry to make beef products more price-competitive, through efficient production, processing and marketing of beef products.

Other substitution relationships in demand shown in Table 4.7 include beef and dairy products, beef and bakery products, and pork and chicken in the short run and in the long run. All the compensated elasticity estimates of the demand for beef with respect to the price of other products are statistically significant, except for the price of bakery products. The compensated cross-price elasticity estimate of the demand for pork with respect to the price of chicken is statistically significant. This finding also reflects a challenge to the pork industry: in addition to the strong substitution relationship of pork with chicken, the expenditure elasticity of demand for pork in the long run is inelastic.

Substitution relationships are also found for chicken and bakery products, and dairy and bakery products, although these estimates are not statistically significant. Complementary relationships appear to apply to pork and dairy, pork and bakery products, and chicken and dairy. Similar to uncompensated elasticity estimates (Table 4.6), long run estimates of own-price and cross-price compensated elasticities are generally higher than short run estimates. This implies that generally the demand for food is more price responsive in the long term than in the short term.

4.6 Summary and Conclusions

The purpose of this component of the thesis was to apply a flexible dynamic model of demand to derive a set of estimates of demand for major meat products and major food categories in Canada. The hypothesis that consumers fully adjust to price and income changes instantaneously in every time period is tested. The results reported here reject this hypothesis, indicating that the basic assumption of a steady state underlying the specification of static demand models may be wrong. Consumers do not make complete instantaneous adjustments but appear to be more responsive to changes in relative price and income in the long run than in the short run. It appears that static models may understate the adjustment in consumers' budget shares as real prices and income change over time.

The results reported here have some implications for modelling and predicting consumer behaviour. Specifying short run demand models and incorporating simple habit persistence may not be appropriate. Estimated relative price and income responses may be biased and predictions of consumer behaviour based on such estimates may be inaccurate. A more general dynamic specification may be required to better predict consumer behaviour. This may be particularly important for policy analyses.

The results from the general dynamic specification employed in the study suggest that food consumed away-from-home and non-food goods are expenditure elastic, both in the short run and in the long run. The demand for chicken, dairy products and bakery products changes from being expenditure inelastic in the short run, to becoming expenditure elastic in the long run. For beef, expenditure elasticity in the long run is not different from the short run, suggesting that there is a tendency for consumers to spend more on goods/commodities other than beef as income increases. The demand for beef is also found to be own-price elastic in the long run but not in the shorter run. Moreover, a strong substitution relationship appears to exist between beef and pork, and beef and chicken. These findings pose potentially serious challenges to the beef industry. Developing products that have increased value to consumers at competitive prices, and responding positively to health, nutrition, and food safety concerns, will be steps in the right direction. For pork, expenditure elasticity declines in the long run and there appears to be a strong substitution relationship between pork and chicken. This finding should also be of concern to the pork industry if it wants to maintain and/or increase its market share in the long run.

4.7 Suggestions for Further Research

Practical necessity and data availability restricted the estimation of demand for disaggregated food commodities. The commodity specifications used in the study were extremely aggregated and may be viewed as overly restrictive. Patterns of consumption of individual foods or food groups vary appreciably. Agriculture and Agri-Food Canada (1990) reports that the relative importance of some major food groups is changing. Consumption of red meats has declined and consumption of poultry, fresh vegetables and fruits, are becoming more important in Canadian diet. Thus, it is important to estimate demand using data series on disaggregated commodities when these are available.

Figure 4.1: Postulated Separability Tree for Canadian Consumers

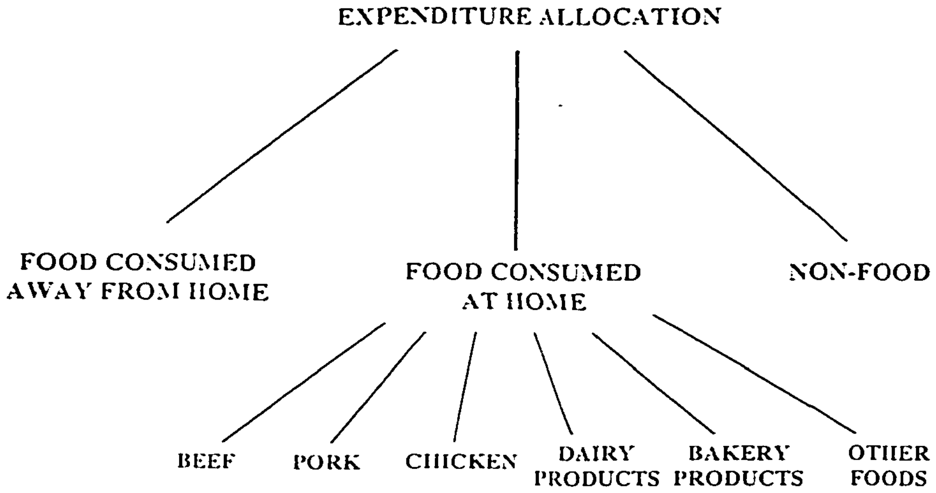

Table 4.1: **Retail Sector Variables: Definitions and Source.**

Variable	Definition	Source
Expenditure on food consumed at home	Annual personal expenditure on food & non-alcoholic beverages in current mS.	CANSIM D16096
Expenditure on food consumed away from home	Annual personal expenditure on restaurants & hotels in current mS.	CANSIM D16137
Expenditure on non-food	Total personal expenditure on goods & services less expenditure on food & restaurants & hotels in current mS.	CANSIM D16141 minus D16096 & D16137
Price index of food consumed away from home	Ratio of restaurant & hotel exp. (current mS) and restaurant & hotel exp. (constant mS - 1992 price)	CANSIM D16137 / D16195
Price index of non-food	Ratio of non-food exp. (current mS) and non-food exp. (constant mS - 1992 price)	Calculated
Expenditure on beef products	Calculated using estimated prices and per capita disappearance	Calculated
Expenditure on pork products	Calculated using estimated prices and per capita disappearance	Calculated
Expenditure on chicken products	Calculated using estimated prices and per capita disappearance	Calculated
Expenditure on dairy products	Final Demand (current mS)	CANSIM I383506
Expenditure on bakery products	Final Demand (current mS) for wheat flour & starches; Breakfast cereal & bakery food snacks	CANSIM I383906 and I384006
Beef products price	CPI for beef	CANSIM P100005 and Chen (1991)
Pork products price	CPI for pork	CANSIM P100006 and Chen (1991)
Chicken products price	CPI for chicken	CANSIM P100009
Dairy products price	CPI for dairy products	CANSIM P100020
Bakery products price	CPI for bakery and other cereal	CANSIM P100027

Table 4.2: Estimated Coefficients of the Flexible Dynamic LAIDS Model of Retail Demand for Food[a].

Parameter	Estimate	t-ratio	Parameter	Estimate	t-ratio
λ	0.435	14.183	u_{PD}	-0.002	-0.136
a_{A}	-0.003	-1.315	u_{PK}	-0.013	-1.629
a_{AA}	0.024	3.944	u_{P0}	-0.001	-0.313
a_{AN}	-0.024	-2.904	$\hat{u}_{PP}$	0.035	4.404
a_{A0}	0.010	1.271	$\hat{u}_{PC}$	0.010	3.192
$\bar{a}_{AA}$	0.023	2.124	$\hat{u}_{PD}$	-0.008	-1.759
$\bar{a}_{AN}$	-0.029	-2.626	$\hat{u}_{PK}$	-0.010	-3.042
$\bar{a}_{A0}$	0.019	2.883	$\hat{u}_{P0}$	0.028	1.615
a_{N}	0.010	0.923	u_{C}	0.001	0.255
a_{NN}	0.033	2.198	u_{CC}	0.022	2.038
a_{N0}	0.011	0.489	u_{CD}	0.010	0.751
$\bar{a}_{NN}$	0.069	4.327	u_{CK}	0.014	1.457
$\bar{a}_{N0}$	0.063	3.737	u_{C0}	0.0004	0.234
u_{B}	0.002	0.350	$\hat{u}_{CC}$	0.019	3.847
u_{BB}	-0.022	-1.495	$\hat{u}_{CD}$	-0.005	-0.878
u_{BP}	0.023	1.668	$\hat{u}_{CK}$	0.006	1.149
u_{BC}	0.013	2.008	$\hat{u}_{C0}$	-0.0004	-0.062
u_{BD}	0.004	0.548	u_{D}	0.004	0.711
u_{BK}	-0.005	-0.783	u_{DD}	0.015	0.545
u_{B0}	0.004	1.879	u_{DK}	0.030	2.009
$\hat{u}_{BB}$	0.040	6.501	u_{D0}	0.005	1.667
$\hat{u}_{BP}$	0.004	0.801	$\hat{u}_{DD}$	0.053	4.419
$\hat{u}_{BC}$	0.006	2.223	$\hat{u}_{DK}$	-0.010	-1.230
$\hat{u}_{BD}$	-0.002	-0.489	$\hat{u}_{D0}$	-0.034	-3.120
$\hat{u}_{BK}$	-0.004	-1.252	u_{K}	0.010	2.415
$\hat{u}_{B0}$	0.009	0.575	u_{KK}	0.029	1.798
u_{P}	-0.003	-0.506	u_{K0}	0.004	1.951
u_{PP}	0.032	1.736	$\hat{u}_{KK}$	0.037	3.073
u_{PC}	0.029	3.537	$\hat{u}_{K0}$	-0.007	-0.854

[a] the subscripts denote 0=expenditure; A=food consumed away-from-home; N=nonfood group; B=beef; 4=Pork; 5=Chicken; 6=Dairy products; and K=Bakery products.

Table 4.3: Estimated Uncompensated Elasticity Measures for First-stage Income Allocation of Retail Demand for Food[a].

	Short run Elasticities			Long run Elasticities		
	---------*prices*---------			---------*prices*----------		
	FA	NF	EXP	FA	NF	EXP
Evaluated at 1961-1997						
Food-Away (FA)	-0.692[a]	-0.057[a]	1.270[a]	-0.680[a]	-0.041[a]	1.145
Non-Food (NF)	-0.477[a]	-0.976[a]	1.079[a]	-0.354[a]	-0.969[a]	1.014[a]
Evaluated at 1991-1997						
Food-Away (FA)	-0.686[a]	-0.055[a]	1.275[a]	-0.674[a]	-0.040[a]	1.147[a]
Non-Food (NF)	-0.484[a]	-0.979[a]	1.076[a]	-0.360[a]	-0.971[a]	1.013[a]

[a] indicates statistical significance at the 5% level.

Table 4.4: Estimated Compensated Price Elasticity Measures for First-stage Income Allocation of Retail Demand for Food[a].

	Short run Elasticities		Long run Elasticities	
	-----prices-----		*-----prices-----*	
	FA	NF	FA	NF
Evaluated at 1961-1997				
Food-Away (FA)	-0.601[a]	0.034[a]	-0.598[a]	0.040[a]
Non-Food (NF)	0.375[a]	-0.123[a]	0.447[a]	-0.168[a]
Evaluated at 1991-1997				
Food-Away (FA)	-0.597[a]	0.034[a]	-0.593[a]	0.040[a]
Non-Food (NF)	0.405[a]	-0.090[a]	0.478[a]	-0.133[a]

[a] indicates statistical significance at the 5% level.

Table 4.5: Comparison of Estimated Uncompensated Short-run Demand Elasticity Measures with those from Other Studies.

	This study (1961-97)	Moschini & Moro (1962-88)	Veeman & Peng (1979-93)
Stage 1:			
Food away			
Own-price	-0.692	-0.52	
Expenditure	1.27	1.05	
Non-food			
Own-price	-0.976	-0.96	
Expenditure	1.079	1.13	
Stage 2:			
Beef			
Own-price	-0.558	-0.50	-0.874
Expenditure	1.099	0.93	0.975
Pork			
Own-price	-0.430	-0.62	-0.752
Expenditure	1.485	1.00	1.013
Chicken			
Own-price	-0.309	-0.72	-0.691
Expenditure	0.984	1.51	0.933
Dairy			
Own-price	-0.535	-0.36[a]	-0.593[b]
Expenditure	0.725	0.47	0.055
Bakery			
Own-price	-0.546	-0.45	
Expenditure	0.919	0.88	

[a] The elasticity estimate is that of milk. In that study, cheese, other dairy and butter are included in the system of equations as separate commodities.

[b] The elasticity estimate is that of whole milk. In that study, low-fat milk and concentrated milk are specified separately as part of the system of equations.

Table 4.6: Estimated Uncompensated Elasticity Measures for Food Consumed at Home[a,b].

	Shortrun Elasticities						Longrun Elasticities					
	prices						*prices*					
	Beef	Pork	Chicken	Dairy	Bakery	Exp.	Beef	Pork	Chicken	Dairy	Bakery	Exp.
[at 1961-1997]												
Beef	-0.558[a]	0.065	0.216[a]	-0.025	-0.053	1.099[a]	-1.255[a]	0.387	0.452[a]	0.032	-0.066	1.050[a]
Pork	0.020	-0.430[a]	0.342[a]	-0.092[a]	-0.150[a]	1.485[a]	0.257	-0.453	1.033[a]	-0.012	-0.152	0.984[a]
Chicken	0.071[a]	0.178[a]	-0.309[b]	-0.042	0.067	0.984[a]	0.143[a]	0.494[a]	-0.214	0.076	0.163	1.016[a]
Dairy	0.012	-0.103	-0.155	-0.535[a]	-0.087	0.725[a]	0.045	-0.032	0.337	-0.888[a]	0.360[a]	1.042[a]
Bakery	-0.034	-0.167[a]	0.205	-0.074	-0.546	0.919[a]	-0.062	-0.224	0.483	0.240[a]	-0.654[a]	1.053[a]
[at 1991-1997]												
Beef	-0.298[a]	0.097	0.182[a]	-0.027	-0.053	1.156[a]	-1.399[a]	0.555[b]	0.384[a]	0.036	-0.066	1.079[a]
Pork	0.048	-0.173	0.286[a]	-0.101[a]	-0.150[a]	1.695[a]	0.404[b]	-0.217	0.879[a]	-0.013	-0.152	0.978[a]
Chicken	0.111[a]	0.254[a]	-0.413[a]	-0.047	0.067	0.986[a]	0.225[a]	0.708[a]	-0.331	0.086	0.163	1.014[a]
Dairy	-0.001	-0.162	-0.127	-0.480[a]	-0.087	0.689[a]	0.075	-0.044	0.286	-0.873[a]	0.360[a]	1.047[a]
Bakery	-0.058	-0.242[a]	0.175	-0.085	-0.546[a]	0.919[a]	-0.095	-0.318	0.410	0.272[a]	-0.654[a]	1.053[a]

[a] indicates statistical significance at the 5% level.
[b] indicates statistical significance at the 10% level.

Table 4.7: Estimated Compensated Price Elasticity Measures for Food Consumed at Home[a,b].

	Short-run Elasticity Measures					Long-run Elasticity Measures				
	prices					*prices*				
	Beef	Pork	Chicken	Dairy	Bakery	Beef	Pork	Chicken	Dairy	Bakery
[at 1961-1997]										
Beef	-0.461[a]	0.163[b]	0.314[a]	0.073[a]	0.045	-1.161[a]	0.480[a]	0.545[a]	0.125[b]	0.027
Pork	0.106[b]	-0.344[a]	0.428[a]	-0.006	-0.064	0.314[a]	-0.396	1.090[a]	0.045	-0.095
Chicken	0.098[a]	0.205[a]	-0.282	-0.015	0.094	0.171[a]	0.523[a]	-0.185	0.105	0.191[b]
Dairy	0.102[a]	-0.013	-0.065	-0.445[a]	0.003	0.175[b]	0.097	0.466	-0.759[a]	0.490[a]
Bakery	0.042	-0.091	0.281	0.002	-0.470[a]	0.025	-0.136	0.570[b]	0.328[a]	-0.566[a]
[at 1991-1997]										
Beef	-0.233[a]	0.162	0.247[a]	0.038	0.013	-1.338[a]	0.616[b]	0.444[a]	0.097	-0.005
Pork	0.117	-0.104	0.355[a]	-0.032	-0.081[a]	0.444[b]	-0.178	0.918[a]	0.026	-0.113
Chicken	0.144[a]	0.286[a]	-0.380[a]	-0.015	0.099[b]	0.258[a]	0.741[a]	-0.298	0.119	0.196[b]
Dairy	0.075	-0.086	-0.051	-0.797[a]	-0.011	0.190	0.071	0.401	-0.758[a]	0.476[a]
Bakery	0.019	-0.166[a]	0.251[b]	-0.008	-0.470[a]	-0.008	-0.231	0.497[b]	0.359[a]	-0.566[a]

[a] indicates statistical significance at the 5% level.
[b] indicates statistical significance at the 10% level.

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Appendix 4a: Elasticity Formulation for the Flexible Dynamic LAIDS Model.

Following Burton and Young (1992), elasticity measures are calculated as:

Short run Uncompensated Elasticity Measures:

Expenditure elasticity measure for the first stage: $\eta_i^{SR} = \dfrac{b_{i0}}{c_i} + 1$

Expenditure elasticity measure for the second stage: $\eta_k^{SR} = \dfrac{v_{k0}}{c_k} + 1$

Price elasticity measures for the first stage: $\mathrm{E}_{ij}^{SR} = \dfrac{b_{ij} - c_i c_j(\eta_i^{SR} - 1)}{c_j} - \theta_{ij}$

Price elasticity measures for the second stage: $\mathrm{E}_{kl}^{SR} = \dfrac{v_{kl} - c_k c_l(\eta_k^{SR} - 1)}{c_l} - \theta_{kl}$

where c_i and c_k are the expenditure shares of product i and good k respectively; and θ_{ij} and θ_{ij} are unity if $i=j$: $k=l$ and zero otherwise.

Long run Uncompensated Elasticity Measures:

Expenditure elasticity measure for the first stage: $\eta_i^{LR} = \dfrac{a_{i0}}{c_i} + 1$

Expenditure elasticity measure for the second stage: $\eta_k^{LR} = \dfrac{u_{k0}}{c_k} + 1$

Price elasticity measures for the first stage: $\mathrm{E}_{ij}^{LR} = \dfrac{a_{ij} - c_i c_j(\eta_i^{LR} - 1)}{c_j} - \theta_{ij}$

Price elasticity measures for the second stage: $\mathrm{E}_{kl}^{LR} = \dfrac{u_{kl} - c_k c_l(\eta_k^{LR} - 1)}{c_k} - \theta_{kl}$

Compensated Elasticity Measures:

Compensated elasticity measures are calculated using the Slutsky relationship:

First stage compensated measures: $\mathrm{E}_{ij}^{\text{comp}} = \mathrm{E}_{ij}^{\text{uncomp}} + \eta_i c_i$

Second stage compensated measures: $\mathrm{E}_{kl}^{\text{comp}} = \mathrm{E}_{kl}^{\text{uncomp}} + \eta_k c_k$

Appendix 4b: Data Series Used for the Retail Sector Model

Year	HF exp	FA exp	NF exp	Meat exp	Beef exp	Pork exp	Chicken exp	Dairy exp	Bakery exp	OF exp	HF price	FA price	NF price	Beef cpi	Pork cpi	Chicken Cpi	Dairy cpi	Bakery cpi	FA cpi	NF cpi	OF cpi
1961	4948	1674	19332	848.7	412.14	330.05	106.51	694.02	483.14	2922.15	122.3	12.8	20.2	18.07	24.11	19.7	17.4	17.2	12.9	19.5	19.7
1962	5230	1806	20645	919.56	463.2	345.68	110.69	722.27	510.58	3077.58	127.3	13.1	20.4	19.83	25.07	20.5	17	17.6	13.1	19.7	20.1
1963	5515	1910	22055	973.18	424.99	426.5	121.68	740.31	533.53	3267.99	131.5	13.5	20.8	14.11	24.87	21.2	16.9	18.4	13.6	20	20.7
1964	5787	2062	23757	1015.22	532.51	372.89	109.81	762.81	575.71	3433.26	133.1	14.1	21.2	18.61	23.91	19.9	17.4	19.3	14.3	20.4	20.9
1965	6119	2244	25866	1107.8	597.71	389.44	120.65	802.5	597.8	3610.9	138	14.6	21.6	19.38	26.56	20.7	17.9	19.4	14.6	20.8	21.6
1966	6621	2455	28273	1276.64	672.67	456.31	147.66	881.13	616.72	3846.52	144.9	15.6	22.3	21.29	30.64	22.5	19.2	19.9	15.7	21.4	22.9
1967	6915	2796	30640	1372.14	724.9	491.44	155.8	924.66	635.37	3982.83	148.4	16.8	23.3	22.44	27.58	21.5	20.5	20.2	16.9	22.3	23
1968	7155	2981	33888	1401.02	758.54	483.75	158.73	932.31	649.01	4172.66	150.3	17.6	24.4	22.82	27.45	21.8	21.2	20.6	17.7	23.3	23.7
1969	7622	3302	37065	1542.28	812.72	546.05	183.51	963.59	663.39	4452.74	160.1	18.7	25.3	24.66	32.13	21.9	22	20.9	18.8	24.4	24.6
1970	7945	3576	39086	1541.28	795.27	562.76	183.24	975.59	674.39	4753.74	158	19.8	26.3	25.43	30.24	21.2	22.1	21.3	19.9	25.3	24.9
1971	8238	3920	42914	1561.68	852.66	533.14	175.88	1019.95	699.13	4957.24	153.1	20.4	27.1	26.1	26.09	22.1	23	21.8	20.8	26.2	25.2
1972	9116	4424	48081	1854.98	984.36	654.14	216.48	1109.45	759.43	5392.14	167.2	21.7	28.1	28.4	32.6	25.4	24.3	22.6	22.1	27.2	27.3
1973	10778	5239	54479	2454.55	1261.44	872.35	320.76	1232.92	856.52	6234.02	199.1	24.1	29.5	34.4	42.87	33.3	26.1	24.7	24.9	28.6	31.5
1974	12790	6272	63127	2725.38	1489.11	876.95	359.32	1521.59	1049.09	7493.94	179.1	27.8	32.3	37.9	40.09	37.8	29.7	30.7	29.6	31.1	36.5
1975	14525	7310	73187	2996.02	1627.23	984.19	384.6	1801.37	1182.75	8544.85	166.3	31.9	35.7	36	51.36	41.7	37.6	36.3	33.8	34.2	40.9
1976	15105	8469	84546	2964.56	1575.9	970.37	418.29	1879.68	1208.58	9052.18	157.7	34.4	39	33.6	53.06	41.7	39.5	36.9	36.7	37.4	41.7
1977	16615	9309	94646	3300.1	1762.53	1050.52	487.05	2071.64	1315.06	9928.2	159.3	36.8	42.2	35.8	50	42	42.5	39.3	38.9	40.3	45.5
1978	18825	10412	105535	4137.02	2286.78	1288.55	561.69	2267.41	1405.21	11015.36	182.5	39.6	45.4	52.3	62.8	48.7	45.6	42.7	41.5	42.9	51.1
1979	21178	11632	117788	4693.06	2592.44	1403.76	696.85	2537.38	1573.39	12374.18	185	44.1	49	68.8	59.7	53.7	49.7	50	46.5	46.3	56.9
1980	23401	13048	132678	4783.12	2679.79	1400.86	702.47	2947.11	1721.61	13949.16	162.3	48.5	54	74.7	58.2	57.8	56.8	57.3	50.8	51	62.4
1981	26201	14606	150307	4976.89	2687.83	1502.92	786.15	3344.06	1979.04	15901	148.8	53.8	60.2	76.6	67.8	68.7	65.1	67.5	55.6	57.5	69.2
1982	28101	15265	161477	5317.16	2771.66	1691.96	853.54	3617.14	2142.52	17024.18	147	60	66.4	76.1	79.9	70.5	71.6	71.4	61.3	64.3	73.6
1983	29264	16088	179555	5240.88	2711.49	1665.39	864	3820.89	2221.39	17980.84	137.2	63.9	71.2	76.7	79.1	73.1	75.4	74.9	64.9	68.4	76.1
1984	31410	17195	196509	5343.13	2767.77	1604.32	971.05	4112.13	2345.11	19609.62	129.9	66.8	74.1	81.7	78.6	77.9	80.4	78.8	67.5	71.2	80.6
1985	32789	18720	216073	5365.33	2775.39	1617.41	972.53	4305.23	2432.51	20685.93	124.6	69.9	77.1	83.8	80.7	74.7	83.5	82	70.3	74.1	82.4

Continued on next page

Appendix 4b continued

1986	34619	20556	234384	5423.34	2669.54	1717.41	1036.38	4491.35	2582.67	22121.64	120.8	73.9	80	85.6	93.7	81.3	85.1	86.4	73.7	77.1	86.7
1987	36670	21962	254787	5615.65	2684.77	1793.1	1137.79	4685.16	2756.48	23612.71	119.9	77.3	83.1	93.4	102.1	86.3	87	88.7	76.7	80.5	90.6
1988	37951	24264	277513	5382.91	2586.59	1658.05	1138.28	4908.61	2879.71	24779.77	109.7	81.2	86.4	94.8	97.1	87.4	90.2	91.8	80.2	84	92.5
1989	39793	27083	299975	5362.47	2495.02	1667.81	1199.64	4982.07	3171.78	26276.67	107.6	85.4	90.2	96.9	98.7	97.5	92.8	94.7	84.3	88.4	95.3
1990	41975	27911	317027	5715.03	2622.15	1730.46	1362.42	5090.24	3373.66	27796.07	112.3	89.4	93.9	100.6	107.5	102.6	95.8	98.3	88.5	92.8	99
1991	43446	27816	328670	5851.56	2702.24	1748.85	1400.48	5113.16	3495.38	28985.9	114.4	98.3	98.2	101.3	105	100.4	99	99.1	98.1	98.2	101.3
1992	43427	28855	340658	5737.7	2559.83	1798.81	1379.06	4963.8	3610.4	29115.1	115.6	100	100	100	100	100	100	100	100	100	100
1993	45036	29873	355253	5963.69	2622.69	1848.01	1492.99	4920.19	3742.29	30409.83	121.2	101.3	102.4	105.4	103.9	102.1	99.5	101.3	101.3	101.9	102.1
1994	45810	31665	370273	5868.36	2567.12	1846.68	1454.56	4949.77	3842.47	31149.4	118.6	102.8	103.4	106.2	105.8	97	99.1	103.2	102.6	102	102.5
1995	47325	32823	382828	5997.59	2629.11	1896.86	1471.62	5049.39	3956.99	32321.03	118.8	105.4	104.5	105.8	108.4	96.7	101.7	107.5	104.6	104.2	104.4
1996	48638	33692	398626	6163.99	2548.43	1962.65	1652.91	5189.48	4066.78	33217.76	118.8	106.9	106.2	101.3	117.1	105.6	103.4	111.6	106.3	105.9	105.6
1997	50198	35324	423636	6361.69	2561.42	2035.5	1764.76	5355.93	4197.21	34283.17	118.8	108.6	108	102.3	122.6	109	106.1	114.3	108.1	107.6	107.1

5. SIMULATION: THE IMPACT OF VALUE-ADDING ON THE FARM SECTOR

5.1 Introduction

Most of Canada's grains/oilseeds production and much of the livestock output is produced in the Prairie provinces of Alberta, Saskatchewan and Manitoba. Much of the grains/oilseeds and pork products is destined for the export market. Domestic demand for agricultural and food products is relatively stable. Thus, apart from influences from weather and technological factors, variations in farm prices and farm incomes are predominantly determined by situations in the international market. Such situations have caused a renewed interest in the concept of "post-farm-gate value adding" by the federal and provincial governments and by the agriculture industry. Consequently, substantial investment has been made in value-added initiatives in the post-farm-gate sector.

Agricultural economists have expended much effort toward evaluating the economic benefits from cost-reducing research in agriculture. Some economic research has generally been carried out by assessing a multi-stage production system in a partial-equilibrium framework. Studies have focused on the distribution of economic benefits from government policy such as investment in research and development (Dryburgh and Doyle 1995; Holloway 1991; Huang and Sexton 1996; Mullen et al. 1989; Voon and Edwards 1991;). Other studies have examined the benefits from investments in commodity promotion and advertising (Cranfield et al. 1995; Kinnucan et al. 1996; Wohlgenant 1993). The literature provides important insights into the effects of different types of exogenous factors on commodity prices and quantities as well as the effects on welfare of particular groups in the food production system. The effects of promotion and/or advertising are evaluated under the assumption that promotion and/or advertising shift the retail demand curve and for research, the effects are evaluated under the assumption that research shifts the farm input supply curves. While this multi-stage approach is equally applicable to estimating the effects of value adding investment, no attention as yet has been given to economic research on this particular issue. This component of the thesis extends the literature on distribution of gains in a multi-stage production system to include gains/losses from investment in value adding in the post-farm-gate sector.

This portion of the study follows and adapts the work of Martin and Alston (1994) who measure the impact of a technological change that shifts the supply curve of farm commodities. This study is concerned with the impact of investment in value added processing that may shift the derived demand curve for farm commodities. Five commodities are examined, namely wheat, feed barley, canola, slaughter cattle and slaughter hogs. Functional equations representing the supply and demand for the commodities are applied in experiments based on the assumption of increased demand for the commodities. Results from the experiments should provide insights into the effects of investment in value adding on prices, quantities and farmers' welfare.

The following section of the study illustrates a conceptual model of the likely impact of value added investments in the processing sector. Following this, sections dealing with the empirical specification of the models, parameterization of the models, solution algorithm of the models, validation of the models, and measurement of changes in farmers' welfare are presented. Simulated results and discussion of these are then presented and some conclusions are drawn from the simulated results.

5.2 Conceptual Model

Figure 5.1 is a simplified diagram illustrating the impact of value-added investment on western Canadian farmers. It is assumed that value-adding activities would increase quantities of farm commodities demanded for domestic processing. From Figure 5.1, the world market determines the domestic price of the commodity **q**. Assuming that government investments in value adding acts as a subsidy that applies to purchasers of the commodity, the effective domestic market demand for **q** moves from **D** to **D'** by a vertical distance equal to the subsidy. This is because more of the **q** is demanded at each market price. One of the effects of this increase in domestic market demand is to shift the excess supply function inwards, from **ES** to **ES'**. The horizontal distance of this latter shift at each price is the same as the horizontal movement from **D** to **D'**.

The effect of these shifts in domestic market demand and the excess supply function on western Canadian farmers depends on the nature of the excess demand function **ED** as perceived by Canada. In panel [A], the excess demand function is downward sloping but near infinitely elastic, indicating that Canada has a fairly small amount of power on the world market to influence the price of **q**. Thus, with a shift in the domestic market demand for **q** and the consequent contraction in the excess supply, the domestic price of **q** increases from w_0 to w_1. In terms of welfare, the gain by producers from the price increase is the shaded area.

In panel [B], the excess demand function that Canada faces is infinitely elastic (horizontal), indicating that Canada has very minimal or no power to influence the price of **q** on world market. The price of **q** is exogenous to Canada. The contraction in the supply of **q** on the world market does not translate into any change in the price of **q**. Consequently, there is no welfare gain by producers from the shift of the domestic market demand from **D** to **D'**.

5.3 Empirical Model

The modelling procedure employed in the study to evaluate the effects of value-added investment lends itself directly to applications of full general equilibrium models but attention focuses on only a few commodity sub-sectors. All the functional relationships specified previously in Chapters 2 to 5 are put together in a partial equilibrium framework and used for simulating the effects of changes in domestic demand for commodities.

The production functions for the farm commodities were derived from a Generalized Leontief profit function (see Chapter 2). From section 2.1 (Chapter 2), the supply functions are represented as:

$$q_i(w) = \frac{\alpha_i}{w_i^{0.5}} + \alpha_{ii} + \sum_{j=2}^{5} \alpha_{ij} \frac{w_j^{0.5}}{w_i^{0.5}} \quad i \neq j \quad \& \quad i,j = 1,\dots,5 \tag{5.1}$$

where q_i is the quantity of commodity i supplied; and w_i is the price. The subscripts i,j are indexed 1=wheat, 2=canola, 3=slaughter cattle, 4=slaughter hogs and 5= feed barley. Equation (5.1) differs from equation (2.18) in that the constant term α_{ii}, in (5.1) subsumes the effects of the fixed and quasi-fixed factors. Similarly, the demand functions for the farm commodities were derived from a Translog profit function (see Chapter 3, section 3.4). The demand functions are represented as:

$$s_i = \frac{w_i q_i^d}{\Pi} = -(b_i + b_{i*} \ln p_k + b_{ii} \ln w_i) \qquad i = 1,\dots,4 \tag{5.2}$$

where s_i is the cost of the commodity to total profit; Π is the processor profit; q_i^d is the quantity of the commodity demanded domestically; and p_k is the price of the output k produced from commodity i.

It is assumed that feed barley is used mainly as livestock feed. Consequently, the demand function for barley (i=5) is specified as a linear function of the price of slaughter cattle, slaughter hogs and barley:

$$q_5^d = \sigma_0 + \sum_j \sigma_{ij} w_j \qquad j = 3,\ldots,5 \tag{5.3}$$

where q_5^d is the quantity of barley demanded and the σs are parameters.

Regarding output from the processors, the following correspondence is made between commodities and output: Wheat is used to produce wheat flour, canola is used to produce canola oil, and slaughter cattle and slaughter hogs are used to produce meat products[18]. Thus, from the processor profit function, the supply functions for processor output are represented by:

$$s_k = \frac{p_k x_k}{\Pi} = b_k + b_{kk} \ln p_k + b_{ki} \ln w_i \qquad k = 1,\ldots,3 \tag{5.4}$$

where the subscript k is indexed as 1=wheat flour, 2= canola oil, and 3=meat[19]. Equations (5.2) and (5.4) differ from equation (3.24) and (3.25) in that the intercept terms b_i and b_k subsume other intermediate and marketing inputs such as labour and energy. Other variables are defined as earlier.

[18] Data on the meat processing industry output obtained from Statistics Canada are aggregated and include abattoir operations and meat packing operations.
[19] The equation for meat products includes the price of both slaughter cattle and slaughter hogs.

The demand for processors' output is represented by the linear version of the almost ideal demand system (chapter 4, section 4.2.2). The share equations for the products are expressed as:

$$c_k = \alpha_k + \sum_l \alpha_{kl} \ln p_l + \beta_k \ln(\frac{M}{P^*}) \qquad k,l = 1,\ldots,4 \tag{5.5}$$

where c_k is the share of product k in consumer expenditure $(p_k x_k^d / M)$; x_k^d is the quantity of product k demanded on the domestic market; M is total expenditure; and P^* is Stone's price index. In equation (5.5) the subscripts k and l are indexed 1=wheat flour, 2=canola oil, 3=beef, and 4=pork. The αs and β_k are parameters. The following relationship is used to link the output of meat products and the retail products of beef and pork:

$$x_{meat} \equiv \theta + x_3^{ex} + x_4^{ex} + x_3^{ex} + x_4^{ex} \tag{5.6}$$

where x_k^{ex} is the quantity of beef and pork exported; and θ is a parameter that captures other livestock products besides beef and pork such as veal and mutton. Similarly, the price of meat products is linked to the price of beef and pork as:

$$p_{meat} \equiv \pi_0 + \sum_{k=3}^{4} \pi_k p_k \tag{5.7}$$

where the πs are parameters.

To complete the model some market closing identities (market equilibrium conditions) and other price linkages need to be established. The commodity market closing identities are represented as:

$$q_i \equiv q_i^d + q_i^x \qquad i = 1,\ldots,5 \tag{5.8}$$

where q_i^x is export of commodity i. For feed barley, q_i^x is denoted by a parameter that accounts for stocks. The product market closing identities are represented as:

$$x_k^d \equiv \lambda_0 + \lambda_k x_k^{d*} + x_k^x \qquad k = 1,\ldots,4 \qquad (5.9)$$

where x_k^{d*} is the retail demand for product k; x_k^x is the quantity of product exported; and the λs are parameters. The parameter λ_0 subsumes stocks of the product k and λ_k is a conversion factor. For example, beef and pork are converted from carcass weight to retail weight using λ_k=0.73 and λ_k=0.76 for beef and pork respectively (Veeman and Peng 1997). The market closing identities of equations (5.8) and (5.9) ensure that total supply equals total demand.

For wheat, canola, slaughter cattle and slaughter hogs, export supply functions are specified as functions of own price, that is,

$$q_i^x = \phi_0 + \phi_1 w_i \qquad i = 1,\ldots,4 \qquad (5.10)$$

where the ϕs are parameters.

Other price linkage equations involve relationships between processor output price and farm commodity price. These are specified as:

$$p_k = \delta_0 + \delta_1 w_i \qquad i,k = 1,\ldots,4 \qquad (5.11)$$

where the δs are parameters.

The complete model consisted of 34 variables and 36 equations and the solution method followed to solve the model was to treat the model as a collection of linear and non-linear algebraic equations. The system of equations was then solved using software, GAMS (General Algebraic Modeling System) and the CONOPT solver (Brooke et al. 1996). The process involved the following steps:

1. Solve the system of equations to obtain optimal solutions for the variables (base case).
2. Validate the model by introducing a shock of a 50% increase in grain/oilseed prices and resolve the system of equations to obtain new solutions for prices and quantities.
3. Conduct other shock experiments by increasing domestic demand of each commodity by 20% and resolve the system to obtain new solutions for prices and quantities besides the fixed demand levels.
4. For each solution, calculate the changes in quantity, price and farmers' welfare.

Unfortunately, the solution for the system of equations contained some infeasibilities and required reparametrization. Moreover, the complete model failed a validation test (see section 5.5 below). Therefore, the supply and demand functions for processor output were eliminated from the system. The resulting model used in the study consisted of 22 variables and 22 equations (see Appendix 5).

5.4 Model Parameterization

With the model specification as above, the next step is to determine the values of the model parameters that appear in the equations. In the literature, two procedures are used to obtain the parametric values; by stochastic procedure and/or by a deterministic procedure. With the stochastic procedure, the equations of the system are estimated simultaneously by econometric techniques using time series data (e.g., Kinnucan et al. 1996; Wahl et al. 1992; Weerahewa 1996). This procedure has the advantage of allowing statistical tests on the estimated parameters. In addition, the parameters are calculated on the basis of average relationships exhibited between the dependent and independent variables over a period of time. Thus, out of sample projections could be more accurate. In spite of the advantages of the stochastic procedure, a major problem is infeasibility because of problems with degrees of freedom. Moreover, in such multi-stage models where market-clearing conditions are included, the likelihood function of the system of equations will not be well defined since there are restrictions on parameters (Rodriguez 1974).

The alternative deterministic procedure is followed in this study. It involves calibrating the equations to a base period using elasticity estimates from the literature and occasionally by econometric estimation to fix the values of certain parameters (e.g., Adilu 1998; Dryburgh and Doyle 1995; Holloway 1991; Martin and Alston 1994; Wohlgenant 1993). For the present study, elasticity estimates from chapters 2, 3 and 4 are used to calibrate the supply and demand relationships of equations (5.1) to (5.5)[20]. Econometric estimates are used to calibrate the relationships in equations (5.7), (5.10) and (5.11). One implication of calibration is that the model cannot be statistically tested since the parameters are chosen in a deterministic way. In addition, a fundamental assumption in calibration is that the market is in equilibrium in the base period. Hence, the model can be used to perform different comparative static analyses from changes in exogenous variables.

5.5 Model Validation

Model validation is important in empirical analysis particularly, for predictive analysis. Validation refers to exercises that determine whether the model behaviour is close enough to real world behaviour (McCarl and Spreen 1984). Where stochastic procedures are used to parameterize the model, the commonly used validation statistics are Correlation coefficient, Root Mean Square Error, and statistics obtained by regressing actual on predicted values. The purpose of examining the statistics is to ascertain how well the simulated values predict the actual data.

Where deterministic procedures are applied to parameterize the model as in this study, models are frequently validated using historical events. Models are constructed and validated or justified in one of several ways:

1. The right procedures are followed where the modelling approach is consistent with industry, previous research and/or theory and that data are specified using reasonable scientific estimation and accounting procedures (e.g., Cranfield et al. 1995; Martin and Alston 1994).
2. Trial results indicate the model is behaving satisfactorily and does not contradict perceptions of reality (e.g., Kinnucan, Xiao and Hsia 1996; Wahl, Hayes and Johnson 1992).
3. The data are set up in a manner so that the real world outcome is replicated (e.g., Adilu 1998; Benirschka et al. 1996).

A review of the various model validation procedures reveals that the process of validation is fundamentally subjective (McCarl and Spreen 1984). Modellers choose the validity tests, the criteria for passing those tests, what model outputs to validate, what setting to test in, what data to use, etc. Nonetheless, validation exercises improve model performance and provide insights into the issues being examined. In this study, two procedures of validation by model construction are followed:

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[20] Elasticity estimates from chapter 4 that are used for the calibration are uncompensated estimates.

1. The modelling approach in this study utilizes functional relationships that are derived from duality approaches in economic theory rather than the ad hoc linear relationships specified in the literature (e.g., Cranfield et al. 1995; Wahl, Hayes and Johnson 1992). The modelling approach is also consistent with industry structure and previous research (e.g., Martin and Alston 1994).
2. Trial results from this study indicate the model behaves satisfactorily and does not contradict perceptions of reality. This is accomplished using the behaviour of commodity prices, which are known to move together (Bewley et al. 1987; Burt and Worthington 1988; Coyle 1993: Shumway et al. 1987). A sharp increase in the price of one commodity results in corresponding increases in the price of other commodities.

5.6 Welfare Measures

The economic welfare measure depicted in Figure 5.1 apply to linear demand and supply relations involving a single commodity. The system of equations derived and applied in the present study involves more than one commodity. Thus, changes in the quantity demanded of one commodity result in changes in the price of other commodities. Just et al. (1982, p. 337-343) provide procedures for evaluating welfare of a multiple price change. In the farm commodity market, this procedure involves evaluating producer (processor) surplus by integrating with respect to commodity prices above (below) the commodity supply (demand) curve. This approach amounts first, to differentiating the profit functions with respect to price(s) and then integrating with respect to the same price(s). The profit function must be expressed as the integral over all of the supply functions with respect to prices, with integration undertaken one price at a time (Just et al. 1982, p. 340). This need for integration with respect to all prices makes the calculation of economic surplus difficult to undertake. Consequently, producer welfare is evaluated in this study using changes in producer profit. Producer profit (Π^f) is calculated as:

$$\Pi^f = 2\sum_{i=1}^{5}\alpha_i w_i^{0.5} + \sum_{i=1}^{5}\sum_{j=1}^{5}\alpha_{ij} w_i^{0.5} w_j^{0.5} \qquad i,j = 1,\ldots,5 \qquad (5.12)$$

All variables are defined as previously. The αs identified in equation (5.1) are used to parameterize equation 5.12.

5.7 Results and Discussion

The analysis of the effects of value adding investment follow the nature of the model. The base solution represents the initial market equilibrium conditions. Exogenous shocks to the system affect the initial equilibrium causing imbalances in the market. The variables then adjust to establish a new market equilibrium. From economic theory, it is assumed that changes in the price variables trigger changes in quantity variables and/or vice versa. Thus the model solution illustrates price and quantity responses and cross-commodity substitutions. The changes that occur in the variables contain both direct and indirect effects of the introduced shocks but it is difficult to distinguish between the two effects. However, it may be assumed that the direct effects are relatively larger than the indirect effects. This ensures the stability of the system.

5.7.1 Effects of Increases in Commodity Prices

Table 5.1 reports the effects of a 50% increase in the price of commodities. The values reported in the table are percentage changes from the base solution. The purpose of these experiments is to verify whether prices of commodities move together. It is a means of validating or justifying the performance of the model for predictive policy scenarios. Since commodity prices are known to move together, it is expected that with a shock in one commodity price, other prices will move along in the same direction. For example in 1973, a sudden increase in demand for wheat on the world market resulted in sharp increases in commodity prices, particularly for wheat, and a significant increase in the export of wheat from Canada. Consequently, assessing the effect of a 50% increase in the price of wheat can be used to validate the model used in this study as the model solution is compared to the real world results.

5.7.1.1 Effects of a 50% Increase in Wheat Price

This experiment is conducted by introducing a 50% increase in the price of wheat. The model solution is presented in Table 5.1. All commodity prices increased from the base solution except the price of hogs, which declined by 4.35%. The price of barley increased by 28.65%, the price of canola by 117.73% and the price of slaughter cattle by 3.98% (Table 5.1). The rise in the price of wheat triggered a response in supply with wheat production increasing by 12.55%. Production of barley and canola did not respond to the rise in the prices. Canola production declined by 5.57%. These effects may be attributed to substitution effects in production from increased wheat production.

The increase in grain/oilseed prices resulted in a decline in domestic demand for the commodities. Domestic demand for wheat decreased by 86.1% while canola demand decreased by 77.12%. Regarding exports, there are significant increases in wheat and canola exports. Exports of wheat and canola increased by 40.8% and 438% respectively.

In the livestock sector, with a 50% increase in the price of wheat, the price of hogs decreased by 4.35% nonetheless, production increased by 179.17% and domestic demand also increased by 145.14%. With a relatively high domestic demand for hogs compared to production, exports of live hogs decreased by 39.02%. Cattle price increased by 3.98%, probably causing the observed decline in domestic demand (13.3%). Production also declined by 8.29%. With a low domestic demand for cattle, exports increased by 123.53%. In terms of farmers' welfare, total profits increased by 327.77% making farmers better off than from the base solution.

5.7.1.2 Effects of a 50% Increase in Barley Price

A second experiment is conducted where the price of barley is increased by 50% to observe the effects on prices and quantities. Results from that scenario are also presented in Table 5.1. All commodity prices increased except the price of hogs, which decreased by 4.53%. The price of wheat, canola, and cattle increased by 45.2%, 100.45% and 3.98% respectively. With a rise in the price of barley, there was a consequent increase in production by 11.3%. The production of wheat remained fairly constant while canola production declined by 5.57%. These effects may also be attributed to substitution in production between the commodities since it is implicit in the functional specifications that land allocation is fixed. The increase in wheat and canola price resulted in a decrease in domestic demand for the commodities. Domestic demand for wheat declined by 86.1% and domestic demand for canola fell by 72.45%. Wheat exports increased by 40.73%, and canola exports by 362%.

Regarding the effects on livestock, the price of hogs declined by 4.53% and yet production increased by 187.5%. Domestic demand for hogs also increase by 152.57% probably resulting in the observed decline in hog exports. In the cattle industry, there was a rise in price but production and domestic demand declined. However cattle exports increased. In terms of welfare, farmers are better off with total profit increasing by 407.82%.

5.7.1.3 Effects of a 50% Increase in Canola Price

This experiment involved introducing a 50% increase in the price of canola. The model solution is also presented in Tables 5.1. All commodity prices increased from the base solution except the price of hogs. The price of wheat increased by 29.38%, the price of barley by 14.89% and the price of slaughter cattle by 2.18% (Table 5.1). The rise in the price of canola triggered a response in supply with canola production increasing by 30.31%. Production of wheat and barley did not respond significantly to the rise in the prices. These effects may also be attributed to substitution effects in production.

The increase in commodity prices resulted in a decline in domestic demand for the commodities. Domestic demand for wheat decreased by 65.07% while canola demand decreased by 50.05%. Regarding exports, there are significant increases in wheat and canola exports. Exports of wheat and canola increased by 40.57% and 140% respectively.

In the livestock sector, the price of hogs decreased by 4.35% but that of cattle increased by a modest 2.18%. The production of hogs increased by 95.83% and domestic demand also increased by 185.71%. With a relatively high domestic demand for hogs compared to production, exports of live hogs decreased by 21.14%. Domestic demand for cattle declined by 6.82%. Production also declined and with the low domestic demand, cattle exports increased by 67.65%. In terms of farmers' welfare, total profits increased by 180.44% making farmers better off.

In summary, it can be observed that an increase in the price of one of the grains/oilseed commodities caused a significant increase in the price of other grains/oilseed and not the price of livestock. An increase in the price of a grains/oilseed commodity resulted in an increase in production and a fairly constant or declines in the production of others. This effect may be attributed to substitution between commodities in production. An implicit assumption underlying the models is that land is fixed hence, there is competition for the land resource in production. Thus, the model solution illustrates price and quantity response and cross-commodity substitutions. In line with economic theory, changes in price variables triggered changes in quantity variables.

High prices also caused domestic demand to fall and increased exports, particularly for wheat and canola. Farmers' welfare increased significantly with an increase in the price of grains/oilseed.

5.7.2 *Effects of an Increase in Domestic Demand for Commodities*

Table 5.2 reports the effects of a 20% increase in domestic demand for grain/oilseed and livestock. The values reported in the table are percentage changes from the base solution. These experiments were conducted to verify the effects of government projections of domestic demand for commodities through increased value adding activities in the processing sector.

5.7.2.1 Effects of a 20% Increase in Domestic Demand for Wheat

With an increase in domestic wheat demand, the price of wheat declined by 9.04% and barley by 2.81%. There is however an increase in canola price. With the decline in prices, wheat and barley production experienced some decline in production. Canola production declined as well. The decline in barley price did not result in an increase in domestic demand for this grain. The increase in the price of canola caused the domestic demand for this oilseed to fall by 4.19%. Canola export increased by 60%, which probably explains the increase in canola price. Wheat exports also increased by 10.78%. This volume of export was not enough to result in a rise in wheat price. The changes in wheat and canola exports appear to be more pronounced than the changes in production of the commodities. The effects on barley were quite minimal. Though the price of barley declined by 2.81%, domestic demand declined and production does not increase. This solution may appear counter-intuitive but considering the fact that barley is used as feed for the livestock industry, we observe that the production of cattle and hogs did not increase (Table 5.2). Therefore, this result may not necessarily be counter-intuitive. Changes in the hog industry were modest and it appears that the cattle industry was not affected by the increase in domestic wheat demand.

In terms of welfare, producer profits declined by 5.77%, which may be attributed to the unrealized increase in farm prices, particularly for the grains. Wheat and barley production is very significant in western Canada. The findings from this scenario, given in Table 5.1 underscore the fact that variation in farm prices (particularly in the price of grain and oilseed) and variation in farm incomes are predominantly determined by situations in the international market.

5.7.2.2 Effects of a 20% Increase in Domestic Demand for Canola

From Table 5.2, a 20% increase in the domestic demand for canola caused an increase in the price of canola by 5.45% but a decline in the price of wheat and barley. With an increase in price, canola production increased by 21.06%. The production of wheat and barley declined which may be attributed to the decline in price and to substitution effects in production with canola. Exports of canola increased by 50%. The decline in wheat price however, caused an increase in domestic demand for wheat by 21.69%. In view of the results given in section 5.7.1 above, it is hard to explain why wheat exports in this scenario increased by 49.61% and yet the price of wheat fell. The effect on barley was not that pronounced. Unlike wheat, a significant amount of canola is processed locally. Thus, the finding of an increase in canola price and production with an increase in domestic demand may be in order.

An increase in the domestic demand for canola resulted in an increase in hog price but a decrease in cattle price. Nonetheless, the production of both cattle and hogs decreased by 0.32 and 11.11 respectively. The domestic demand for the two commodities also declined and for exports, hogs exported increased by 3.25% while export of cattle decreased by 5.88%.

5.7.2.3 Effects of a 20% Increase in Domestic Demand for Cattle

Table 5.2 also reports the effects of a 20% increase in domestic demand for slaughter cattle and hogs. With a 20% increase in domestic cattle demand, the price of cattle declines by 1.14% instead of increasing. The price decline appears contrary to expectation, nevertheless there is an increase in cattle production by 16.9% suggesting a positive net effect for the cattle industry. Export of cattle decreased by 64.71%. The price of hogs fell by 0.18% but hog production increased by 4.86%. However, the decrease in hog price resulted in an increase in the domestic demand for hogs by 42.86%. Export of hogs decreased by 1.63%.

Changes in the prices and production of the crops were modest but significant in the quantities exported. The price of barley was unchanged yet production and domestic demand decreased. This solution appears counter-intuitive to the increased production of cattle and hog production. It was expected that an increase in the production of cattle and hogs would result in an increase in domestic demand for barley.

In terms of producer welfare, total profits increased by 5.09%. The significant increase in the production of cattle and hogs coupled with the relatively stable livestock prices, may have contributed to the increase in farmers' welfare. This solution may suggest that farmers will be better off with increased investments and capacity-expansions in the domestic cattle slaughtering industry.

5.7.2.4 Effects of a 20% Increase in Domestic Demand for Hogs

Generally, a 20% increase in domestic demand for slaughter hogs resulted in price increase for all the five commodities ranging from 0.09% to 1.13% (Table 5.3). The price rise did not cause much change in commodity supply except in hog production. The production of hogs increased by 2.78%. There was no change in hog exports. With a price increase, the domestic demand for wheat, canola and cattle decreased. The quantity of canola and cattle exported increased by 20 and 2.94% respectively. The effects on barley were minimal.

In terms of producer welfare, total profits increased by 4.72%, which may be attributed to the resulting increases in commodity prices. This solution is consistent with the solution from the cattle scenario above, in which farmers may be better off with capacity expansions in the domestic meat processing industry.

In summary, an increase in the domestic demand of commodities resulted in a very small effect on commodity prices. As a result, the increase in farmers' profits is also minimal. Changes in quantity variables did not trigger changes in price variables suggesting that in Canada, commodity prices and are exogenously determined and predominantly by situations in the international market. Consequently, farmers' incomes are also determined predominantly by situations in the international market. This suggests that the belief that increasing domestic demand for commodities due to value adding investments would boost commodity prices and farmers' incomes may not be necessarily realized in the short term.

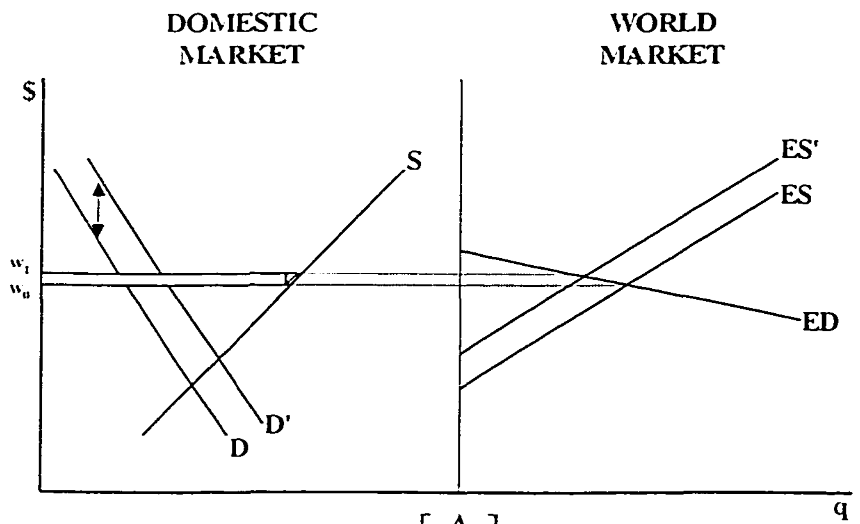
5.8 Summary and Conclusions

This portion of the thesis attempted to evaluate the impact of value-added investment in the post-farm-gate sector on prices, quantities and welfare of western

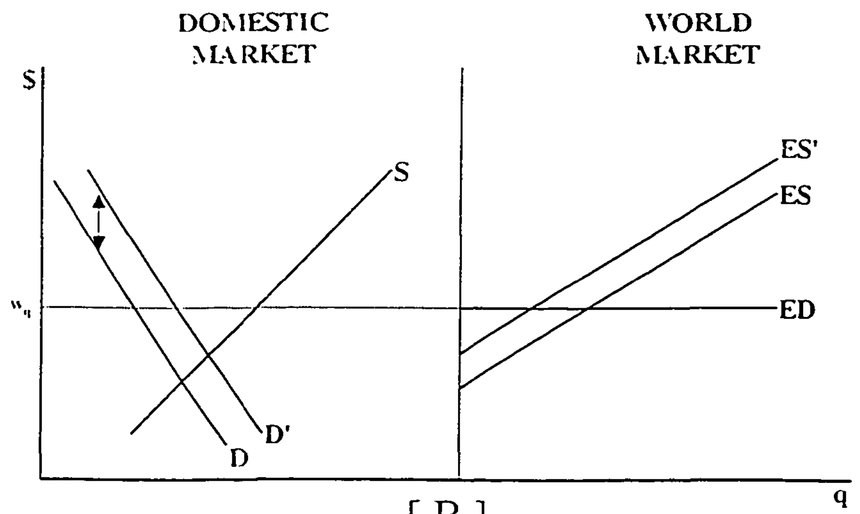
Canadian farmers. The model used in these analyses consisted of a system of commodity supply and demand relationships, market equilibrium conditions and price linkage relationships. The system of equations was first solved for initial equilibrium conditions. Then shocks were introduced to destabilize the system and the system resolved to obtain new equilibrium conditions.

Research investment in value added processing is assumed to enhance demand for primary commodities through improvement in product quality and production of new and alternative products causing an outward shift in the demand curve for farm commodities. The resulting effects would include price and quantity responses as well as cross-commodity substitution in production. Overall, the various simulation results allude to the expectations that farmers will be better off with increased prices of grains/oilseed. However, the results indicate that increases in commodity prices cannot be realized in the short term from increased domestic demand for commodities. Currently, commodity prices appear to be exogenously determined. Nonetheless, results suggest that, to a smaller extent, increased domestic demand for cattle and hogs may increase farmers' welfare. Value-added investment in the livestock and canola processing industries appears to provide some short-term returns in contrast to value-added investment in the wheat milling industry.

Figure 5.1: Hypothesised Effects of Value Added Investments



[A]



[B]

Table 5.1 Effects of 50% Increase in Commodity Price

	Percentage change (%) from base solution		
Variable	50% increase in wheat price	50% increase in barley price	50% increase in canola price
Wheat production	12.55	1.78	4.06
Barley production	0.54	11.30	0.27
Canola production	-5.57	-5.57	30.31
Cattle production	-8.29	-6.57	-4.09
Hog production	179.17	187.50	95.83
Wheat price	50.54	45.20	29.38
Barley price	28.65	50.69	14.89
Canola price	117.73	100.45	50.00
Cattle price	3.98	3.98	2.18
Hog price	-4.35	-4.53	-2.36
Flour price	29.76	25.46	16.69
Oil price	130.22	111.51	55.40
Meat price	-0.21	-0.31	-0.10
Wheat demand	-86.10	-86.10	-65.07
Barley demand	1.12	2.06	0.57
Canola demand	-77.12	-72.45	-50.05
Cattle demand	-13.30	-11.51	-6.82
Hogs demand	145.14	152.57	185.71
Wheat export	40.80	40.73	40.57
Cattle export	123.53	123.53	67.65
Hogs export	-39.02	-40.65	-21.14
Canola export	438.00	362.00	140.00
Producer profit	327.77	407.82	180.44

Table 5.2 **Effects of 20% Increase in Domestic Demand for Commodities**

	Percentage change (%) from base solution			
Variable	20% increase in domestic demand for wheat	20% increase in domestic demand for canola	20% increase in domestic demand for cattle	20% increase in domestic demand for hogs
Wheat production	-4.09	-3.12	0.68	-1.80
Barley production	-0.06	-0.02	-0.19	0.01
Canola production	-3.59	21.06	-1.89	-1.04
Cattle production	0.00	-0.32	16.90	-0.11
Hog production	-0.69	-11.11	4.86	2.78
Wheat price	-9.04	-6.21	2.26	1.13
Barley price	-2.81	-1.40	0.00	0.28
Canola price	2.73	5.45	1.36	0.91
Cattle price	0.00	-0.19	-1.14	0.09
Hog price	0.09	0.36	-0.18	0.18
Flour price	-5.40	-3.71	1.18	0.51
Oil price	2.88	6.12	1.44	0.72
Meat price	0.00	0.00	-0.84	0.00
Wheat demand	19.99	21.69	-6.34	-2.61
Barley demand	-0.12	-0.04	-0.40	0.01
Canola demand	-4.19	20.11	-2.19	-1.24
Cattle demand	0.00	-0.11	20.00	-0.22
Hogs demand	-9.52	-95.24	42.86	19.05
Wheat export	10.78	49.61	49.70	0.01
Cattle export	0.00	-5.88	-64.71	2.94
Hogs export	0.81	3.25	-1.63	0.00
Canola export	60.00	50.00	30.00	20.00
Producer profit	-5.77	-1.42	5.09	4.72

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Appendix 5a: Empirical Model

Structure	Equation*	Commodity
Farm Supply	$q_i(w) = \frac{\alpha_i}{w_i^{0.5}} + \alpha_{ii} + \sum_{j=2}^{5} \alpha_{ij} \frac{w_j^{0.5}}{w_i^{0.5}} \quad i \neq j \quad \& \quad i,j = 1,...,5$	Wheat, Canola, Barley, Cattle and Hogs
Processor Demand	$s_i = \frac{w_i q_i^d}{\Pi} = -(b_i + b_{i\bullet} \ln p_k + b_{ii} \ln w_i) \qquad i = 1,...,4$	Wheat, Canola, Cattle and Hogs
	$q_5^d = \sigma_0 + \sum_j \sigma_{ij} w_j \qquad j = 3,...,5$	Barley
Processor Output	$s_k = \frac{p_k x_k}{\Pi} = b_k + b_{k\bullet} \ln p_k + b_{ki} \ln w_i \qquad k = 1,...,3$	Wheat flour, canola oil, and meat
Farm Market Closing Identities	$q_i \equiv q_i^d + q_i^x \qquad i = 1,..., 5$	Wheat, Canola, Barley, Cattle and Hogs
Export Function	$q_i^x = \phi_0 + \phi_1 w_i \qquad i = 1,...,4$	Wheat, Canola, Cattle and Hogs

* The subscripts i,j are indexed 1=wheat, 2=canola, 3=slaughter cattle, 4=slaughter hogs and 5= feed barley; and the subscript k is indexed as 1=wheat flour, 2= canola oil, and 3=meat

6. GENERAL DISCUSSION AND CONCLUSIONS

6.1 Introduction

The purpose of the thesis is to assess the impacts of post-farm-gate value added activities on western Canadian agriculture. Value adding activities in the form of research and development projects in the post-farm-gate sector are assumed to result in increased demand for primary commodities produced in western Canada. The hope is that value-adding activities will contribute to economic development, sustained prosperity, and adaptation in the changing agricultural environment. Thus, the thesis aims at assessing the effects of value adding on the production of primary commodities, prices and the welfare of farmers. Primary commodities that are considered in the thesis include wheat, barley, canola, slaughter cattle and slaughter hogs.

The procedure adapted to achieve the objectives of the thesis was first, to establish the type of relationships among the commodities considered in the study. Second, the nature of the market for these primary commodities was assessed and finally, experiments were conducted to provide insights into the effects of the assumed increased demand for commodities resulting from post-farm-gate value adding activities. The effects assessed are changes in prices, quantities and producer welfare in the form of profits.

6.2 Results

The results indicate significant economic interrelationships among wheat, barley, canola, slaughter cattle and slaughter hogs at the farm sector. The supply of each of the commodities is positively related to its own price. Wheat production and barley production appear as complements but canola production appears to be a substitute to wheat production. The results also indicate jointness in the production of grains and oilseeds. Hog production is positively related to the prices of wheat, barley and canola. Cattle production is positively related to the price of barley. The results indicate non-jointness in the production of cattle and hogs and jointness in the production of hogs and barley.

The results from the assessment of the market for farm commodities indicate that the demand curves for slaughter cattle, wheat, feed barley, canola and labour are downward sloping. Labour and the five farm commodities are found to be complements in the food production process. On the issue of the existence of market power held by processors, there is no evidence of non-competitive behaviour in any of the commodity markets examined. The absence of non-competitive behaviour may be attributed to factors such as the structure of the commodity markets, increased competition from world trade, technical change, and cost economies of food processing operations.

Results from the simulation exercises corroborate the earlier finding that production of commodities is positively related to the price, and that substitution and complementary relationships exist among the commodities. The results indicate that an increase in the price of one commodity results in an increase in the production of the commodity and a fairly constant or decline in the production of others. An implicit assumption underlying the simulation model is that land is fixed. Hence, there is competition for the land resource in production. Thus, the model solution illustrates price and quantity response and cross-commodity substitutions. High prices of commodities cause domestic demand to fall and exports to increase, particularly for wheat and canola. Farmers' welfare increased significantly with an increase in the price of grains/oilseed.

Experiments conducted by increasing the quantity of commodities demanded on the domestic market resulted in a very small effect on commodity prices. As a result, the increase in farmers' profits is also minimal. Changes in quantity variables did not trigger changes in price variables suggesting that in Canada, commodity prices are exogenously determined and predominantly by situations in the international market. Consequently, farmers' incomes are also determined predominantly by situations in the international market. The belief that increasing domestic demand for commodities (through increased value adding) would boost commodity prices and farmers' incomes may not be realized in the short term. Thus, there are no immediate benefits to farmers from the funding that governments have spent on value added investments. Any anticipated benefits to farmers would require significant marketing strategies, policy shifts in the agricultural sector and/or structural changes in the agricultural industry.

6.3 Recommendations

It is clear from the results that the volume of Canadian agricultural commodities traded on the world market is too small to permit Canada to influence world price[21]. On an individual commodity basis however, Canada may be able to influence the price that farmers receive. As Figure 5.1 illustrates, shifts in the domestic demand of a commodity can result in a price increase provided the excess demand function that Canada faces on the world market is upward sloping. Figure 5.1 and the results from the simulation

[21] The total Canadian agricultural products exports averaged about 3% of total world agricultural products exports for the period 1992 to 1997 (Food and Agriculture Organization –FAO 1999)

exercises indicate that farmers' welfare is increased with increased commodity price. Prices are determined by the market therefore, there is the need for strategies directed at specific markets to enhance a rise in price. On the foreign market, strategies must be directed at increasing market share. Some strategies could include entrepreneurial spirit and ingenuity in establishing new markets, and positioning commodities in existing markets. Canada's average market shares in the world market for wheat and barley from 1988 to 1997 are about 18% and 19% respectively (Canadian Wheat Board 1999; Food and Agriculture Organization 1999; International Grains Council 1999). Canada's share of the world market for canola is about 48%. Even without a focus on enhancing a rise in commodity prices, farmers' revenues per unit of production could be increased and sustained with increased exports of commodities if the world price of commodities remain constant.

Canada's potential to influence prices on the world market depends critically on the world demand for commodities, which is erratic. Consequently, domestic value-added processing has been seen as an opportunity for guaranteed markets that would facilitate high prices of commodities. Adding value to enhance the price of commodities will be effective when an appreciable proportion of domestic production is processed domestically and a smaller proportion of the commodity is exported. The current development of new value-added processing opportunities on the Prairies (e.g., canola crushing plants and livestock slaughter facilities) will provide some economic activity in the Prairies. However, these activities will not enhance the price of commodities at the farm gate, which will continue to be set by the world price, less transportation cost. The loss of direct support from the government means that farmers will continue to face the full impact of downturns in agricultural commodity prices.

Although farmer involvement in processing can take many forms, the formation of new structures of co-operation and vertical co-ordination in the food chain must be given special attention. New management structures are required to meet the challenges of the new agricultural economy. The "New Generation Co-operatives" (NGCs) initiated in the US in North Dakota and Minnesota provide a potential model to follow. New Generation Co-operatives integrate farmers into domestic processing activities, with focus on vertical integration between these levels. Such arrangements provide farmers with a set price for their primary commodities as well as earnings from the processing and value adding activities. Thus, NGCs may have the potential with respect to first, their inherent ability to compete in value-added products market and second, providing ways of generating and sustaining producers' revenues from the marketplace.

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